UNIVERSIDADE DE LISBOA

Faculdade de Medicina de Lisboa

Sinais quantitativos e qualitativos sugestivos de lesão cerebral na Escala de Inteligência de Wechsler para Adultos 3ª Edição (WAIS-III)

Marta de Assunção Gonçalves-Montera

Orientadores:

Professor Doutor Alexandre Lemos de Castro Caldas

Professor Doutor Mário Manuel Rodrigues Simões

Tese especialmente elaborada para a obtenção do Grau Doutor em Ciências Biomédicas, Especialidade Neurociências

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GENERAL INDEX

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LIST OF PUBLICATIONS

Each of the studies presented in this thesis was first presented as an oral communication or as a poster. After each discussion at the scientific events, all these studies have being transformed into scientific papers, three are already published or in press, one is submitted and two are in preparation. Here is the list of the publications:

- Study 1 - Systematic review:
  - Gonçalves, M. A., Simões, M. R., & Castro-Caldas, A. (2014). Systematic review on WAIS-III: A special focus on acquired brain injury. *Journal of the International Neuropsychological Society, 20*(S2), 2-3. doi: 10.1017/S1355617714001003
  - Gonçalves, M.A., Simões, M.R. & Castro-Caldas, A. (2015). A systematic review on WAIS-III's research with a special focus on clinical studies. *E-Psi, 5*(2), 51-85. Retrieved from www.revistaepsi.com/wp-content/uploads/artigos/2015/Ano5-Volume2-Artigo4.pdf
- Study 2 - Brain tumor:
  - Gonçalves, M.A., Simões, M.R, & Castro-Caldas, A. (2014, September). *Sugestões para interpretação dos desempenhos do manual da WAIS-IIII falham na identificação de defeitos cognitivos num grupo de doentes com tumores cerebrais*. Oral communication at the IX Congresso Iberoamericano e Psicologia / II Congresso da Ordem dos Psicólogos Portugueses, Lisboa, Portugal.
  - Gonçalves, M.A., Simões, M.R., & Castro-Caldas, A. (2016). Interpreting WAIS-III performance after primary brain tumor surgery. *Applied Neuropsychology*. doi:10.1080/23279095.2015.1084508 (Published online: 04 Mar 2016)
- Study 3 - Mixed sample:
  - Gonçalves, M.A., Moura, O., Simões, M.R., & Castro-Caldas, A. (2015, October). *Looking for a brain injury in the WAIS-III composite measures*. Oral communication presented at the I Congresso Internacional de Reabilitação Neuropsicológica e o III Simpósio Internacional Neuropsicologia e Reabilitação Congresso, Porto, Portugal.

- Gonçalves, M.A., Moura, O., Castro-Caldas, A., Simões, M.R. ((Published online: 06 Jul 2016)). Searching for a brain injury' s WAIS-III profile. *Applied Neuropsychology*. doi: 10.1080/23279095.2016.1199429

- Study 4 - Lateralized brain lesions:
  - Gonçalves, M.A., Simões, M.R., & Castro-Caldas, A. (2014). Discrepâncias QIV-QIR e ICV-IOP da WAIS-III em lesões cerebrais lateralizadas [VIQ-PIQ and VCI-POI discrepancies of the Portuguese WAIS-III in lateralized brain lesions]. *Sinapse, 13*(1), 104.
  - Gonçalves, M.A., Castro-Caldas, A., & Simões, M.R. (2016, September). WAIS-III: Discriminação entre lesões hemisféricas direitas e esquerdas nas discrepâncias QIV-QIR E ICV-IOP. 3º Congresso da Ordem dos Psicólogos Portugueses, Porto, Portugal.
  - Paper in preparation
- Study 5 - Vocabulary:
  - Gonçalves, M.A., Simões, M.R., & Castro-Caldas, A. (2016, Febuary). *WAIS-III's Vocabulary holds as a good measure of premorbid functioning after brain injury*. Poster presented at the INS 44th Annual Meeting, Boston, Massachussets, USA.
  - Paper under preparation
- Studies 6 and 7 - Short-form:
  - Gonçalves, M.A., Simões, M.R., & Castro-Caldas, A. (2015). Versão abreviada da Escala de Inteligência de Wechsler para Adultos (WAIS-III) para doentes epiléticos candidatos a cirurgia. *Sinapse, 2*(15), 244-245.
  - Gonçalves, M.A., Simões, M.R., & Castro-Caldas, A. (2015, November). Ward's seven subtest short-form of the WAIS-III for brain lesion patients. In Marcelino Pereira (chair), *Avaliação neuropsicológica aplicada*, symposium conducted at the 3º Congresso Internacional do CINEICC/1º Congresso da APTC, Coimbra, Portugal.
  - Gonçalves, M.A., Simões, M.R., & Castro-Caldas, A. (submitted). Ward's subtest short-form of the WAIS-III for patients with drug resistant epilepsy.

ABSTRACT AND KEY-WORDS

OBJECTIVE. The Wechsler Adult Intelligence Scale 3rd edition (WAIS-III) was standardized in Portugal in 2008. The present study aimed to validate this battery of 14 subtests to different groups of acquired brain lesion.

METHODS: A final group of 81 brain injured patients (namely Traumatic Brain Injury, Primary Brain Tumor, Refractory Epilepsy and Cerebro-Vascular Disease) were assessed with a comprehensive neuropsychological battery of tests, which included the Portuguese WAIS-III full form. A control group performance data was selected from the standardization sample, demographically matched to the clinical group regarding gender, age, education, profession and geographic region.

RESULTS: When looking at the WAIS-III full form, results were discouraging, because they failed to discriminate brain injured patients from controls. Statistical differences when present, failed to have clinical implications, because clinical and control groups both performed within the normal range. Yet, multiple regression analysis has demonstrated that brain lesion and literacy influence WAIS-III performance. When partial use of the WAIS-III was taken into account, more encouraging results emerged. Vocabulary raised up as a good measure of premorbid verbal intelligence. A seven subtest short-form with acceptable psychometric qualities was found for the refractory epileptic group.

DISCUSSION: The effects found are not large enough to be of clinical usefulness, but readers should understand that the absence of evidence does not equal evidence of absence. We strongly encourage WAIS-III clinical research to be organized aiming to have homogeneous groups according to brain lesion locations.

WAIS-III, intelligence, neuropsychological assessment, acquired brain lesion, validation

RESUMO EM PORTUGUÊS E PALAVRAS-CHAVE

OBJECTIVO: A Escala de Inteligência de Wechsler para Adultos 3ª edição (WAIS-III) foi aferida a Portugal em 2008. O presente estudo incide na validação clínica desta bateria de 14 subtestes em diferentes grupos de lesão cerebral adquirida

MÉTODO: Um grupo de 81 doentes com diferentes etiologias (nomeadamente Traumatismo Cranio-Encefálico, Tumor Cerebral, Epilepsia Refractária e Doença Cerebrovascular) completou uma avaliação neuropsicológica extensa e compreensiva, na qual estava incluída a versão completa da WAIS-III. Os resultados na WAIS-III foram comparados com os obtidos por uma amostra controlo, selecionada da amostra de aferição, na qual foram emparelhadas as variáveis género, idade, escolaridade, profissão e região de residência.

RESULTADOS: Quando se analisa a WAIS-III como um todo, não foram encontrados resultados que permitam discriminar um doente de um controlo e as diferenças estatisticamente significativas encontradas em diferentes subgrupos não têm implicações clínicas relevantes no diagnóstico de lesão cerebral adquirida. No entanto, a análise de regressão múltipla aponta indubitavelmente a lesão cerebral e literacia como variáveis preditoras do desempenho na WAIS-III. Quando se analisa a utilização de subtestes isolados e/ou de versões abreviadas da bateria, os resultados mostraram-se mais promissores. O Vocabulário demostrou ser uma boa medida de inteligência verbal pré-mórbida. Foi encontrada uma versão reduzida de 7 subtestes com qualidades psicométricas aceitáveis para a avaliação de doentes epilépticos.

DISCUSSÃO: A ausência de efeitos suficientemente robustos para terem implicações clinicas não é sinónimo da presença de uma prova contra a importância utilização da WAIS-III na avaliação da lesão cerebral. Sugerimos que a investigação nesta área deve ser repensada, sugerindo que a selecção das amostras passe a ser feita de modo a assegurar homogeneidade na localização das lesões.

WAIS-III, inteligência, lesão cerebral adquirida, avaliação neuropsicológica, validação

RESUMO ALARGADO EM PORTUGUÊS

Apesar de uma avaliação psicológica ser considerada pelo Sistema Nacional de Saúde um meio auxiliar de diagnóstico e não um meio de tratamento, a verdade é que existem várias semelhanças entre os ensaios clínicos dum medicamento e a aferição e validação dum teste psicológico. Seguindo esta analogia, poderíamos dizer que a etapa pré-clínica do estudo do medicamento se assemelha à etapa de construção do teste e que a etapa clínica, por sua vez, assemelha-se ao que os psicólogos chamam de estandardização, aferição e validação do teste.

Habitualmente, após o términus da etapa de construção do teste, ou da sua adaptação nos casos de tradução (fase pré-clínica), o teste está pronto para passar à fase em que são criadas normas a partir de uma amostra representativa de pessoas ditas normais da população, o que corresponderia à fase I do estudo do medicamento. Além das tabelas de normas, os manuais dos testes costumam também incluir informação de alguns estudos clínicos (fases II e III). Nesta perspectiva, o presente estudo poderia ser chamado de um estudo de fase III, uma vez que se funda no estudo de populações clínicas para o teste mundialmente mais conceituado de avaliação da inteligência, já adaptado e normalizado para Portugal desde 2008: a Escala de Inteligência de Wechsler para Adultos 3ª edição (WAIS-III).

A WAIS-III foi aferida para os Estados Unidos da América em 1997 (n=2450) e depois foi alargada à Austrália (1997, n=297) e ao Reino Unido (1999, n=332). A WAIS-III foi também aferida em Espanha (1999, n=1369), França (2000, n=1104), Canadá (2001, n=1100), México (2003, n=970), Finlândia (2005, n=446), Alemanha, Áustria e Suíça (2006, n=1181) e, finalmente, a Portugal (2008, n=1181). O manual português da WAIS-III (Wechsler, 2008), apresenta os estudos de validade para três amostras clínicas, respectivamente, Epilepsia (n=30), Esquizofrenia (n=26) e Perturbações Depressivas (n=16); bem como os estudos clínicos do manual americano, nomeadamente: (1) quatro grupos nosológicos dentro das Perturbações do Desenvolvimento e Aprendizagem, (2) cinco grupos nosológicos dentro das Perturbações Neurológicas e Relacionadas com a Demência, (3) dois grupos nosológicos dentro das Perturbações Relacionadas com o Álcool e (4) um grupo dentro das Perturbações Neuropsiquiátricas. Em detalhe, os grupos americanos foram (1) Deficiência Mental ligeira (n=46) e moderada (n=62), Perturbação de Hiperactividade de Défice de Atenção ou PHDA (n=30), Perturbações da

Aprendizagem da Leitura (n=24) e do Cálculo (n=22), Deficiência Auditiva (n=30), (2) Doença de Alzheimer (n=35), Doença de Huntington (n=15), Doença de Parkinson (n=10), Traumatismo Cranio-Encefálico ou TCE (n=22), Epilepsia do Lobo Temporal com lobotomia esquerda (n=15) e com lobotomia direita (n=12), (3) Abuso Crónico de Álcool (n=28), Síndrome de Korsakoff (n=10) e (4) Esquizofrenia (n=42).

O OBJECTIVO inicial do presente estudo foi validar a WAIS-III versão portuguesa para algumas amostras neurológicas, procurando explorar sinais quantitativos e/ou qualitativos de lesão cerebral adquirida nos resultados objectivos da bateria ou em qualquer outro tipo de padrão ou resposta, que pudesse servir de sinalizador de lesão cerebral. No entanto, a ausência de resultados positivos levaram a que os objectivos tivessem de ser reformulados ao longo do tempo, primeiro para procurar justificação para a ausência de resultados positivos e, depois, para procurar aquilo que se pode aproveitar desta tão robusta e precisa medida de inteligência para a avaliação neuropsicológica.

MATERIAL E PROCEDIMENTO: Depois da aprovação das Comissões de Ética de três instituições (Centro de Reabilitação Profissional de Gaia, Instituto Português de Oncologia Francisco Gentil e Hospital de Santa Maria) e do consentimento informado de cada doente selecionado pelos médicos, foi feita uma avaliação neuropsicológica, onde na última sessão foi aplicada a versão completa da WAIS-III versão portuguesa. Com excepção da amostra com epilepsia, em que os doentes foram avaliados conjuntamente pela candidata e pela Dra. Ana Catarina Costa e Prof. Lara Caeiro, todos os doentes foram integralmente avaliados pela candidata e receberam um relatório do seu desempenho no final do processo. Os resultados obtidos pelos grupos clínicos foram posteriormente comparados com os resultados obtidos por participantes na amostra de aferição da WAIS-III portuguesa, gentilmente cedidos pela CEGOC-TEA, na pessoa da Dra. Carla Ferreira e emparelhados com os doentes nas variáveis género, idade, escolaridade, profissão e região de residência.

ESTUDO 1: Na revisão sistemática da literatura, procurámos conhecer as amostras clínicas que têm sido estudadas para a WAIS-III além daquelas descritas nos manuais português e americano. Verificámos que a maioria dos estudos se centrava em amostras neurológicas e neuropsiquiátricas, e que apesar de existir uma grande consistência entre os estudos com TCE para encontrar o Índice Velocidade de Processamento deficitário, este

perfil não é exclusivo destes doentes. Constatámos também que, à semelhança do modelo que estávamos a seguir, a selecção das amostras tinha sido feita consoante o grupo nosológico e começámos a questionar se esta selecção não deveria antes ser realizada a partir da localização cerebral da lesão.

ESTUDOS 2, 3 E 7: Ao analisarmos os grupos nosológicos com tumor cerebral (n=22), neurológico misto (n=81) e com epilepsia refractária (n=30) respectivamente, verificámos que apesar de existirem diferenças estatisticamente significativas entre grupo clínico e grupo controlo, essas diferenças não deveriam ter implicações clínicas, pois caso-e-controlo tiveram sempre desempenhos dentro do intervalo considerado normativo.

ESTUDO 3: Verificámos que as variáveis preditoras das diferenças entre grupo neurológico misto e grupo controlo foram: a presença de lesão cerebral, tempo de evolução dessa lesão, idade de início da doença; bem como número de anos de escolaridade.

ESTUDO 4: Com vista a testar a hipótese da importância da localização cerebral comparámos um grupo com lesão cerebral hemisférica direita com um grupo com lesão esquerda. Novamente, os resultados foram desencorajadores e negativos, mas desta vez não inesperados, porque foram semelhantes aos identificados noutros estudos internacionais.

ESTUDO 5: Na busca incessante de diferenças entre os grupos, verificámos que o grupo clínico e controlo apresentavam um desempenho consistentemente semelhante para o subteste Vocabulário. Este resultado corrobora estudos, que apontam para o Vocabulário como uma boa medida de inteligência pré-mórbida.

ESTUDOS 6 E 7: Finalmente, procurámos identificar uma versão abreviada ou forma reduzida para a WAIS-III. Estudámos a sua possibilidade para a amostra mista, mas aprofundámos o estudo para a amostra com epilepsia refractária, porque o protocolo de avaliação da cirurgia da epilepsia prevê sempre a sua aplicação na forma completa. Verificámos que as quatro versões abreviadas estudadas têm boas qualidades psicométricas para a amostra controlo, mas nem todas preservam estas boas qualidades psicométricas para o grupo com epilepsia.

DISCUSSÃO: Os resultados obtidos são desencorajadores no que respeita ao uso da bateria completa da WAIS-III versão portuguesa para o despiste e diagnóstico de doentes com lesão cerebral adquirida, porque não foi encontrado um perfil nem algum teste ou índice que conseguisse discriminar doentes de controlos. No entanto, as análises de

regressão linear múltipla confirmam que a presença de lesão cerebral e o tempo de evolução/idade de início da lesão influenciam o desempenho nesta bateria.

Foi levantada a hipótese que as amostras clínicas deverão ser estudadas em função da lesão cerebral e não da doença de base, sendo esta a variável apontada como responsável pela ausência de resultados positivos e a principal limitação de muitos dos nossos estudos. No entanto, no único estudo em que comparámos diferentes localizações de lesão, os resultados foram tão desencorajadores quanto os dos restantes estudos em que comparámos uma doença com um grupo controlo. Ainda assim, mantemos a ideia que é necessário localizar melhor as lesões cerebrais e estudar grupos clínicos mais homogéneos neste aspecto.

Se abandonarmos a linha de investigação do uso da bateria completa e pensarmos em versões abreviadas ou em testes isolados, os resultados são mais animadores. O subteste Vocabulário revelou-se como uma boa medida de inteligência verbal pré-mórbida e encontrámos uma forma reduzida que, com algumas cautelas, poderá ser utilizada nas sucessivas reavaliações pós-cirurgia da epilepsia. Em estudos futuros, seria interessante centrar-nos em testes isolados (e.g., Matrizes ou Memória de Dígitos) ou em grupos de testes que formam Índices (e.g., Índice de Velocidade de Processamento e/ou Índice de Memória de Trabalho).

Por último, o grau de literacia surgiu igualmente como preditor de desempenho dos sete resultados compósitos da bateria na análise de regressão múltipla, mesmo tendo sido controlado nos nossos estudos pelo emparelhamento dos doentes com os controlos no número de anos de escolaridade. Uma vez que as normas nacionais estão organizadas por faixas etárias, mas não por graus de escolaridade, nem pelo cruzamento de idade com escolaridade, deixamos a pista de que esta será uma área de interesse para estudos futuros.

Em conclusão, apesar das limitações das nossas amostras reduzidas e heterogéneas nas características das lesões, os nossos resultados confirmam a influência da lesão cerebral e da literacia no desempenho da WAIS-III. A presença de efeitos insuficientemente robustos para terem implicações clínicas não é sinónimo de uma ausência de efeitos. Assim, não advogamos a tese de que a WAIS-III deva ser eliminada ou descurada da avaliação neuropsicológica; mas defendemos que para que esta bateria continue a ser utilizada na investigação clínica é urgente e necessário que os critérios de selecção das amostras sejam repensados.

BACKGROUND, MAIN GOALS AND MATERIALS

BACKGROUND

"A *psychological test* is a systematic procedure for obtaining samples of behavior, relevant to cognitive or affective functioning, and for scoring and evaluating those samples according to standards. (…) Psychological tests are often described as *standardized* for two reasons, both of which address the need for objectivity in the testing process. The first has to do with the uniformity of procedure in all important aspects of the administration, scoring, and interpretation of tests. (…) The second meaning of standardization concerns the use of standards for the evaluating test results. These standards are most often norms derived from a group of individuals – known as the *normative* or *standardization sample* – in the process of developing the test." (Urbina, 2004, p.1-2).

A psychological test is valued for its psychometric qualities: reliability and validity. Reliability is concerned with minimizing errors of measurement, whereas validity is concerned with maximizing the degree to which the test measures what it purports to measure.

According to Anastasi (2004), reliability typically studies coefficients that were meant to control different sources of errors: (1) inter-scorer differences, (2) time sampling error, (3) content sampling error, (4) inter-item inconsistency, (5) inter-item inconsistency, and content heterogeneity combined, and finally (6) time and content error combined. Respectively, these coefficients are: (1) scorer reliability, (2) test-retest reliability or stability coefficient, (3) alternate-form reliability or split-half reliability, (4) split-half reliability or more stringent internal consistency measures (e.g., Kuder-Richardson 20 or coefficient alpha), (5) internal consistency measures and evidence of homogeneity, and finally (6) delayed alternate-form reliability.

In the classical view of validity, "psychological measures serve three major functions: (1) establishment of a statistical relationship with a particular variable, (2) representation of a specific universe of content, and (3) measurement of psychological traits. Corresponding to these are three types of validity: (1) predictive [or criterion] validity, (2) content validity, and (3) construct validity" (Nunnaly, 1978, p.87). In current perspectives on validity, the term construct validity has evolved greatly (Anastasi, 2004), though the goals of validity remained the same: "the validity of a test concerns *what* the test measures and *how well* it does so" (Anastasi & Urbina, 1988, p. 113)

A fair analogy for the development of a psychological test is the development of a drug (e.g., a pill or syrup), which has two main steps: the pre-clinical and the clinical work. The preclinical work could be compared to the research needed for the creation or the translation and adaptation of a psychological test. On the other hand, the clinical work could be compared to the standardization and validation process.

Usually, when a test is ready to be marketed, the manual includes table norms derived from data collected with a representative sample of national healthy volunteers, the so called normative or standardization sample (phase I of drug development) as well as the information about the reliability and some clinical trials,- the so called validation studies (phase II and, sometimes, phase III). The present study could be described as a phase III study, once we will focus exclusively on the validation of a renowned, but already standardized, battery of intelligence.

The scientific study of individual differences began in the latter part of the 1800s, with Wilhelm Wundt in Leipzig, Germany, and Francis Galton in London, United Kingdom. But it was only in the early 1900s, in France, that Binet and Simon created the first well known battery of intelligence. By the time, Binet-Simon Scales were being translated and adapted for the United States of America at Stanford University; the First World War broke out. In the meantime, Robert M. Yerkes and a committee of psychologists, working for the US Army, developed the Army Tests (Forms Alpha and Beta) to assess all recruits.

David Wechsler spent much time of his early career in the army, during World War I, but he also spent some precious time in London, studying with Charles Spearman and Karl Pearson, and in Paris with Henri Piéron (more details in Boake, 2002 and Tulsky et al, 2003). Wechsler returned from Europe to the USA in 1922, and in 1932 he became the chief psychologist at Bellevue Psychiatric Hospital in New York. He then started the construction of the Wechsler-Bellevue Scale, based on a new rationale, and putting together many already existing tests. Hence he founded a brand new theory about human intelligence and created the most popular and well established intelligence test, from the psychological assessment history.

Since the creation of the Wechsler Adult Intelligence Scale (WAIS), intelligence testing and intelligence theory has evolved much. A close colleague of David Wechsler, Joseph D. Matarazzo (1972) reanalyzed his classical work and pointed new growth of intelligence theory. The multiple intelligence models emerged and new tests to assess them

too. Nevertheless, Wechsler Intelligence Scales (WIS) had never lost the first podium of intelligence testing/assessment.

In short, the WAIS' predecessor was constructed in 1939, and its name was Wechsler-Bellevue Scale (WB-I, Wechsler, 1944). Sixteen years evolved, and after some procedure changes and new norm tables, the W-B became the original WAIS (Wechsler, 1955). Another twenty six years passed and the WAIS' norms were updated with minor item changes, turning the WAIS into the WAIS-R (Wechsler, 1981). After David Wechsler´s death, the WAIS underwent two large revisions and subsequent standardizations, specifically the creation of WAIS-III (The Psychological Corporation, 1997) and WAIS-IV (The Psychological Corporation, 2008).

The WAIS-III was standardized in the United States of America (1997), and extended for Australia (1997) and for the United Kingdom (1999). It was also standardized in Spain (1999), France (2000), Canada (2001), China (2002), Mexico (2003), Finland (2005), Germany, Austria and Switzerland (German version, 2006), and Portugal (2008). Sweden (2003) and Denmark (2005) only translated the battery. South Africa (2010) published the preliminary studies on the standardization of the WAIS-III.

WAIS-5's data collection for English speaking population is currently active, and Pearson predicts it will close in Winter 2017. Though as far as we know, there are no WAIS-IV or WAIS-5 standardizations for Portuguese speaking population. Therefore, from now on, we will exclusively focus on WAIS-III on this thesis.

Furthermore, before enumerating the goals of the present study and describing in detail the tasks included in this scale (i.e. this battery of tests), one last note worth to be mentioned: the importance of the WAIS in the field of neuropsychological assessment.

Although memory, language, visuospatial abilities, and executive functions take the lead role in the neuropsychological assessment; intelligence is one of cognitive dimensions that still need to be assessed. As said before, the first podium of intelligence testing goes to WIS and their IQ scores, but the IQ concept is controversial among neuropsychologists.

Back to 1988, Muriel D. Lezak offered "a funeral oration for a concept that, when young, served psychology well by giving it a metric basis… [but now] …the central problem with the IQ concept was succinctly stated by Thurstone in 1946 when he observed that it, 'tends so to blur the description of a man that his mental assets and limitations are buried in a single index'. Nowhere does this blurring become more apparent than in

neuropsychology where most examinations are conducted on persons whose mental functioning is only partially impaired: rarely does brain damage erode all mental functions equally…" (p.351-352). Yet, Rabin, Paolillo and Barr's (2016) survey about test-usage practices of clinical neuropsychologists in the United States and Canada still gives the first podium to the Wechsler Adult Intelligence Scales, and two of the most important handbooks of neuropsychological assessment (Strauss, Sherman & Spreen, 2006; Lezak, Howieson, Bigler & Tranel, 2012) still present the WAIS various versions as the first test used for intelligence assessment.

Strauss, Sherman and Spreen (2006) stated the unquestionable: a Wechsler Adult Intelligence Scales "is one of the most frequently used measures in neuropsychology batteries and is often used considered 'the gold standard' in intelligence testing. It is a core instrument, giving information about the overall level of intellectual functioning and the presence or absence of significant intellectual disability, and providing clues for altered functions" (p.283). And Glascher et al (2009) stated one possible explanation to the unavoidable importance of the WAIS, once it "is the single most widely used instrument for measuring intelligence today. Despite its construction as a test of cognitive of aptitude, the WAIS is ubiquitous in neuropsychological batteries that assess impairment. It has excellent psychometric properties, very high test-retest reliability in both health and clinical populations, and an enormous database to provide comparison and standardization."

Therefore, the need of research on WAIS-III among neurological populations has decades of tradition and still a promising future for clinical practice.

According to The Psychological Corporation (2008), Kaufman and Lichtenberger (1999), Tulsky et al. (2003), and Gonçalves, Simões and Castro-Caldas (2015) most of the WAIS-III validation and/or clinical research are conducted in the context of neuropsychological studies, and its most relevant work is done with Traumatic Brain Injury (TBI), temporal lobe Epilepsy, aging neurodegenerative diseases (such as, Alzheimer's, Huntington's, and Parkinson's Diseases), Mild Cognitive Impairment (MCI), Multiple Sclerosis, Korsakoff's Syndrome, and samples with mixed neuropsychiatric diseases. However, little is known about Portuguese neurological patients in WAIS-III. From what we know there are only three validation studies in Portugal (Wechsler, 2008): pre-surgical temporal lobe epilepsy (n=30), schizophrenia (n=26) and depressive disorders (n=16).

MAIN GOALS

The original goal of this study was to validate the WAIS-III for Portuguese neurological patients. This broader goal had two specific goals: (1) to identify a profile(s) of acquired brain injury, among quantitative scores, that could help diagnosis and/or (2) to identify any qualitative pattern/information, that could help a clinical psychologist with no specific training in neuropsychology tracking brain injury. The absence of positive results made us raise new questions and develop new goals. Hence the goals have changed over time.

Although each chapter will point its specific goal(s), we could summarize the underlying questions in the following list:

1. **Which clinical samples have been studied and how?** (Study 1 - Systematic review - Oral communication + Published paper)
2. **Is there a specific profile for brain tumor patients?** (Study 2 - Brain tumor paper - Oral communication + Published paper)
3. **Which variables are responsible for this absence of profile(s)?** (Study 3 - Mixed sample paper - Oral communication + Paper in press)
4. **Could standardized discrepancies discriminate left from right brain lesions?** (Study 4 - Left *versus* right hemisphere lesion or lateralized brain lesions study – preliminary data presented as an oral communication 2014 + submitted for oral communication)
5. **What holds unchanged after brain injury?** (Study 5 - Vocabulary poster - Poster + Paper in preparation)
6. **A short-form could be of use?** (Study 6's abstract and study 7's paper –Short-form for refractory epileptic patients paper - Oral communications + Paper submitted)

MATERIALS

As mentioned before, the original WB-I was created putting together the best tests available at the time. Half of the tests were labeled verbal and half performance tests, once verbal tests required orally presented and answered questions, and performance tests required more visually our constructive tasks. Wechsler-Bellevue and WAIS had the verbal subtests administered first and the performance subtests afterwards. Since WAIS-R, verbal and performance subtests alternate. The evolution and order of the subtests selected to this battery is presented in Table 1, 2 and 3.

Table 1.
Order of the subtests in the different editions of WAIS and its predecessor

	Wechsler--Bellevue	WAIS	WAIS-R	**WAIS-III**	WAIS-IV
Picture Completion (PC)	7	8	2	**1**	15
Vocabulary (V)	(11)	6	5	**2**	5
Digit-Symbol (Cod)	10	7	10	**3**	10
Similarities (Si)	5	4	11	**4**	2
Block Design (BD)	9	9	6	**5**	1
Arithmetic (A)	3	3	7	**6**	6
Matrix Reasoning (MR)	-	-	-	**7**	4
Digit Span (DS)	4	5	3	**8**	3
Information (I)	1	1	1	**9**	9
Picture Arrangement (PA)	6	10	4	**10**	-
Comprehension (C)	2	2	9	**11**	13
Symbol Search (SS)	-	-	-	**12**	7
Letter Number Sequencing (LNS)	-	-	-	**13**	11
Object Assembly (OA)	8	11	8	**14**	-
Visual Puzzles	-	-	-	**-**	8
Figure Weights	-	-	-	**-**	12
Cancelation	-	-	-	**-**	14

Note:
Vocabulary is once put between parentheses, because it was not co-normed with the other subtests.

In the **Picture Completion** (PC) test, the examinee has to indicate the missing part of a picture, within a 20-second time limit. The WAIS-III items look different from the previous versions, as they have been redrawn in color to look more contemporary. Instructions and scoring system have not changed over time; but the number of items has been increasing, from 15 in the WB-I to 25 in the WAIS-III. This subtest has no sample items, but if the examinee fails the first two items, new instructions are added to help the

examinee to better interpret the task. Items are scored as 1 (correct) or 0 (incorrect, no response or correct answer when time was out). The subtest is discontinued after five consecutive scores of zero.

In the **Vocabulary** (V) test, the examinee is required to provide a definition in his/her own words. The task and the scoring rules have not changed across the various versions, only the word list has suffered modifications. This is the single subtest that has been decreasing the number of items over time, from 42 in the WB-I to 33 in the WAIS-III. Like the previous subtest, there are no sample items, and extra instructions are stated at the manual, only for occasions when clarification is needed. Answers are scored according to its richness with 0, 1 or 2 points. The subtest is discontinued after six consecutive zero scores.

In the **Digit Symbol Coding** (Cod) test, the examinee is instructed to copy symbols that are paired with numbers. Using a key, the examinee draws each symbol under the corresponding number. Before the examinee starts, the examiner demonstrates three trial items, and the examinee is asked to complete four other trial items. The examinee is encouraged to work as fast as he/she can, but no bonus points will be added to the final score if the examinee ends before the time is up. Extra instructions are stated at the manual, to say only once, in case the examinee skips an item or starts to do only items of one type (e.g., only the 1's). The test is discontinued after 120 seconds and items are scored 1 (correct) or 0 (incorrect).

In the **Similarities** (Si) test, the examinee is asked to verbally state how two words that represent common objects or concepts are alike. The task and the scoring rules have not changed across the various versions, only the word pairs list has suffered modifications. The number of items has been increasing over time, from 12 in the WB-I to 19 in the WAIS-III.

Like Vocabulary, answers are scored 0, 1 or 2 according to its richness, and extra instructions are stated at the manual for occasions when clarification is needed. Corrections are aloud, but only once, when the examinee fails to score two on the first item administered. In this case, extra instructions are stated at the manual to help the examinee to reach a higher level of abstraction. The subtest is discontinued after four consecutive scores of zero.

In the **Block Design** (BD) test, the examinee must use blocks with different colored sides (white, red and half red/white) to replicate the model or picture from the stimulus booklet. Like all other WAIS-III subtests other than Digit Symbol Coding and Symbol

Search, the items progress in difficulty from simple to more complex designs. There are two two-block designs, seven four-block designs and five four-block designs. Sixty seconds are allowed for two and four-block designs, and 120 seconds are allowed for nine-block designs. Previous versions of the WAIS-III usually had four and nine-block designs (there was a 16-blocks design in the WB-I though), and the number of items has doubled from seven in the WB-I to 14 in the WAIS-III. The examinee is encouraged to work as fast as he/she can, and bonus points will be added to the final score of 1 (correct) from item seven to item fourteen. The item will be scored zero, even if correct, when the time is up. There are no trial items, but corrections and demonstrations are allowed in a standardized manner stated at the manual for the first six items. The subtest is discontinued after three consecutive scores of zero.

In the **Arithmetic** (A) test, the examinee is asked to mentally solve arithmetic word problems and to answer orally. Like Block Design, the number of items has doubled over time, from 10 in the WB-I to 20 in the WAIS-III. Curiously, the algorithms haven't changed much over time; but to keep the problems contemporary, the wording has sometimes changed a lot. Answers are scored 0 (incorrect or time's'up) or 1 (correct). Unlike other verbal subtests, this subtest has limited time to answer (15, 30 and 60 seconds), but no bonus points will be added if the answer is given long before the time is up. The examiner can repeat once each item under examinee request, but written cards or partial instructions are not allowed. The subtest is discontinued after four consecutive scores of zero.

In the **Matrix Reasoning** (MR) test, the examinee has to identify by number or point to one of five response options that complete the matrix. There are four types of nonverbal reasoning tasks in this subtest: pattern completion, classification, analogy, and serial reasoning. This is the first out of three brand new tests in this battery. There are three trial items that stay unscored. Like other performance subtests, scores are 1 for correct answers and 0 for incorrect. There is no time limit for this subtest and it has 26 items. The subtest is discontinued after four consecutive scores of zero or four scores of 0 on five consecutive items.

In the **Digit Span** (DS) test, there are two tasks: Digits Forward and Digits Backwards. On both tasks, the examiner reads a series of number sequences to the examinee at the rate of one number per second. For each Digit Forward item, the examinee is required to repeat the number sequence is the same order as presented. For Digits Backwards, the examinee is required to repeat the number sequence in the reverse order.

Only items with two digit sequences have changed over time, all other Forward and Backward sequences haven't change from WB-I to WAIS-III. Each item has two trials that should be scored zero if incorrect, or one if correct. The subtest is discontinued after a score of zero on both trials of any item.

In the **Information** (I) test, the examinee has to answer orally to a list of questions that tap general knowledge about common events, places, and people. The number of items hasn't changed much over time, from 25 in the WB-I to 29 in the WAIS and WAIS-R, and finally 28 in the WAIS-III. Answers are scored zero (incorrect) or one (correct) point. The subtest is discontinued after six consecutive scores of zero.

In the **Picture Arrangement** (PA) test, the examinee is asked to rearrange a set of picture cards, mixed-up in a specific order, to create a story that is logical, as if it was a cartoon. The items have time limit, but not time-bonus points. The first item will be corrected with standardized instructions, if the examinee fails the first trial. No other item has two trials and no further help will be given. The number of items almost doubled over time, from six in the WB-I to 11 in the WAIS-III. Like the previous version, near half of the items have more than one solution. The subtest is discontinued after four consecutive scores of zero.

In the **Comprehension** (C) test, the first supplementary subtest, the examinee responds orally to a series of questions about everyday problems or understanding of concepts and social practices. Like Vocabulary and Similarities, task and scoring system hasn't changed much over time, only the number of items and their content has changed. The number of items almost doubled, from 10 in the WB-I to 18 in the WAIS-III. Responses are scored 0, 1 or 2 according to its richness, and extra instructions are stated at the manual for occasions when clarification is needed. The subtest is discontinued after four consecutive scores of zero.

In the **Symbol Search** (SS) test, the second supplementary subtest and the second new subtest in this battery, the examinee is presented with a series of paired groups, each pair consisting of a target group and a search group. The examinee is asked to decide whether of the target symbol is in the search group. Like Digit Symbol Coding, before the examinee starts, the examiner demonstrates two trial items, and the examinee is asked to complete two other trial items. The examinee is encouraged to work as fast as he/she can, but no bonus points will be added to the final score if the examinee ends before the time is up. The final score will be the difference of correct and incorrect answers. This subtest has 60 items, and it should be discontinued after 120 seconds.

In the **Letter-Number Sequencing** (LNS) test, the third supplementary subtest and the third new subtest in this battery, the examinee is read a combination of numbers and letters, at the rate of one number/letter per second, and at the end he/she is asked to recall the numbers first in ascending order and then the letters in alphabetic order. Five practice trials will be done before starting, and all five will remain unscored. Each item will have three trials and the subtest is discontinued after scores of zero on all three trials of an item.

In the **Object Assembly** test, the last and optional subtest of this battery, the examinee is required to assemble puzzles of common objects, within a time limit. This subtest has time limits and time-bonus points. The number of items has been increasing over time, from three in the WB-I to five in the WAIS-III. All items should be administered, though there is no discontinuing rule.

Table 2.
Number of items per subtest in the different editions of WAIS and its predecessor

	Wechsler-Bellevue	WAIS	WAIS-R	**WAIS-III**
Picture Completion (PC)	15	21	20	**25**
Vocabulary (V)	42	40	35	**33**
Digit-Symbol (Cod)	67	90	93	**133**
Similarities (Si)	12	13	14	**19**
Block Design (BD)	7	10	9	**14**
Arithmetic (A)	10	14	14	**20**
Matrix Reasoning (MR)	0	0	0	**26**
Digit Span (DS): forward + backwards	9+8	9+8	7+7	**8+7**
Information (I)	25	29	29	**28**
Picture Arrangement (PA)	6	8	10	**11**
Comprehension (C)	10	14	16	**18**
Symbol Search (SS)	0	0	0	**60**
Letter Number Sequencing (LNS)	0	0	0	**21**
Object Assembly (OA)	3	4	5	**5**

Table 3.
WAIS-III modifications (comparing with WAIS-R)

	Administration and scoring	Time limits and bonus for fast answers	New items
Picture Completion (PC)	Similar	Same: limit and no bonus	14 out of 25
Vocabulary (V)	Similar	Same: no limit nor bonus	9 out of 33
Digit-Symbol (Cod)	Similar	Different	40 out of 133
Similarities (Si)	Similar	Same: no limit nor bonus	8 out of 19
Block Design (BD)	Similar	Similar: limits and bonus	4 out of 14
Arithmetic (A)	Similar	Similar: limits and bonus	6 out of 20
Matrix Reasoning (MR)	New test	No limits nor bonus	All 26
Digit Span (DS): forward + backwards	Almost the same	Exactly the same	1 out of 15
Information (I)	Similar	Same: no limit nor bonus	10 out of 26
Picture Arrangement (PA)	Similar	Similar: limits and bonus	6 out of 11
Comprehension (C)	Similar	Same: no limit nor bonus	6 out of 18
Symbol Search (SS)	New test	120'' limit + no bonus	All 60
Letter Number Sequencing (LNS)	New test	No limits nor bonus	All 7
Object Assembly (OA)	Similar	Similar: limits and bonus	2 out of 5

Summing up, Tables 2 and 3 show the major differences of the WAIS-III in comparison with its predecessors. It is apparent from these tables that task instructions and scoring system have not changed much, but the number of items and sometimes their content has. However there is a main novelty for WAIS-III, and it is that there are three totally new subtests.

Table 4:

Subtests used to calculate each WAIS-III IQ and each WAIS-III Index

IQ		Indexes	
Verbal IQ (VIQ) =	Vocabulary + Similarities + Arithmetic + Digit Span + Information + Comprehension	Verbal Comprehension (VCI) =	Vocabulary+ Similarities + Information
Performance IQ (PIQ) =	Picture Completion + Digit Symbol + Block Design + Matrix Reasoning + Picture Arrangement	Perceptual Organization (POI) =	Picture Completion + Block Design + Matrix Reasoning
Full Scale IQ (FSIQ) =	VIQ + PIQ	Working Memory (WMI) =	Arithmetic + Digit Span + Letter-Number Sequencing
		Speed of Processing (PSI) =	Digit Symbol + Symbol Search

Like for previous versions of WAIS, after the administration and scoring of each subtest, the examiner sums up total raw scores. These raw scores should be converted to scaled scores according to table norms. These tables are age referenced. Interpretation of the scores will then take place and it will focus on the following: (1) subtest scaled scores,

(2) composite measures (i.e., IQs and Indexes), (3) scatter scores and (4) discrepancies. Table 4 indicates how to calculate each IQ and Index. Clinical inferences will take place after these four step interpretation process.

In conclusion, Wechsler Intelligence Scales, like WAIS, are the gold-standard of intelligence assessment. WAIS-III is also one of the most used tests in neuropsychological assessment. The various versions of the WAIS are possible the best studied psychological tests ever, and the latter Portuguese version of WAIS is the WAIS-III used in this thesis. Most of the WAIS-III's validation studies throughout the world have been with neurological patients, but in Portugal this population is little known. Therefore, all the studies compiled in this thesis appeared in favor of psychometric research, but and above all, in favor of clinical neuropsychological practice.

STUDY 1: SYSTEMATIC REVIEW

Gonçalves, M.A., Simões, M.R. & Castro-Caldas, A. (2015). A systematic review on WAIS-III's research with a special focus on clinical studies. *E-Psi, 5*(2), 51-85.

Title:

Revisão sistemática sobre a WAIS-III com especial interesse nos estudos clínicos

A systematic review on WAIS-III's research with a special focus on clinical studies

RESUMO: Nesta revisão sistemática, pretendeu-se explorar como tem sido estudada a Escala de Inteligência de Wechsler para Adultos 3ª versão (WAIS-III): (1) quais os principais temas de publicados, (2) quais os critérios de inclusão utiizados nos estudos com amostras neurológicas e (3) as principais conclusões dos estudos clinicos/neurológicos/psiquiátricos que utilizaram entre 11 e 14 subtestes da bateria. A pesquisa foi feita através da EBSCO-Host por três vezes (2011, 2013 e 2014), utilizando a palavra-chave "WAIS-III" e limitando a pesquisa a "full text" e "scholarly (peer reviewed) journals". Foram identificados 226 artigos: 23 dos quais foram classificados como não tendo o foco ou resultados centrados na WAIS-III, 28 artigos com foco noutro teste ou tarefa, mas utilizando a WAIS-III, 28 artigos teóricos, 13 artigos sobre formas abreviadas, 46 artigos com amostras de estandardização e 88 artigos com amostras de vários tipos. Como principais conclusões apontamos que (1) o maior número de artigos está publicado em revistas especializadas em neuropsicologia, (2) a maioria das amostras com traumatizados cranioencefálicos são de gravidade moderada-grave e nas amostras chamadas "mistas" não há selecção dos sujeitos respeitando ao local da lesão e, finalmente, (3) não foram encontrados perfis de resposta exclusivos para os doentes com lesão cerebral.

ABSTRACT: This systematic review was performed to explore (1) the main goal of the publications, (2) the inclusion criteria used for the most studied neurological samples, and (3) the main conclusions of the clinical/neurological/psychiatric studies which used the core/whole Wechsler Adult Intelligence Scale third edition (WAIS-III). EBSCO Host database was searched three times (2011, 2013 and 2014) using the keyword "WAIS-III" and the only limiters applied were "full text" and "scholarly (peer reviewed) journals". A total of 226 articles were identified. We classified 23 articles as no WAIS-III focus nor data, 28 as focused on other tests but with WAIS-III data, 28 as theoretical articles, 13 as articles on WAIS-III short-forms, 46 as articles with the technical manual samples, and 88 as articles with various kinds of samples. At the end, we came to the conclusions that (a) most of the articles published on this systematic review have neuropsychological issues as the main target, (b) most TBI samples focus on moderate severity, and in 18 out of 20

articles with the so called “mixed neuropsychiatric samples”, there is no selection of brain injury samples according to injury localization, finally (c) it was not found an exclusive profile specific to brain injury.

Key-words: WAIS-III, brain injury, systematic review

INTRODUCTION

Although Wechsler Adult Intelligence Scale – fourth edition (WAIS-IV) is already available in several non-English speaking countries (namely, France, Germany, Spain, Sweden, Danmark, Norway, Netherlands, India and Chile), many others countries (where Portugal is included) still use the WAIS-III, because they don’t have the WAIS-IV standardization for their countries and/or because there is the clinical information we have now about WAIS-III make it a better clinical instrument than the WAIS-IV.

The Wechsler Adult Intelligence Scale – third edition (WAIS-III) was standardized in the United States of America (1997, n=2450), and extended for Australia (1997, n=297) and for the United Kingdom (1999, n=332). It was also standardized in Spain (1999, n=1369), France (2000, n=1104), Canada (2001, n=1100), China (2002, n=888), Mexico (2003, n=970), Finland (2005, n=446), Germany, Austria and Switzerland (German version, 2006, n=1181), and Portugal (2008, n=1181). Sweden (2003) and Denmark (2005) only translated the battery. South Africa (2010, n=84) published the preliminary studies on the standardization of the WAIS-III.

In 2008, the Portuguese technical manual included the results of the US clinical trial field samples and three national clinical small samples: temporal lobe epilepsy, schizophrenia and depressive states. Although the manual showed the results of the clinical US samples, we decided to look for more. Thus, the main goal of this research was to explore what kind of samples is being studied with the WAIS-III, knowing ahead that we had a special interest on the neurological samples.

In detail, this systematic review was performed to explore (1) the main goal of the publications, (2) the criteria used to select subjects for clinical/neurological studies, and (3) the main conclusions of the clinical/neurological studies which used the core or the whole battery.

METHODS

EBSCO Host database (including PsychARTICLES, PsychINFO, Academic Search Complete, Education Source, and Psychology and Behavior Science Collection) was searched using the keyword "WAIS-III" and the limiters applied were "full text" and "Scholarly (peer reviewed) journals". The search took place in 2011-06-08, 2013-01-29 and 2014-01-14, always using the same search strategy: no language or publication date limiters were applied. Based on this process, 226 articles written in English and in Spanish, dated between 1998 and 2013, were identified.

RESULTS AND DISCUSSION

(1) Classifying the publications according to main target and to main goal

As shown in table 1, the three journals that published more articles on WAIS-III were journals focused on Neuropsychology. Table 1, also shows that the years with more publications are almost a decade after the US publication of the battery (1997), the top publication years vary from 2005 to 2010. Analyzing the journals that published more articles at table 1, it seems that this battery, initially made for intelligence and intellectual disabilities assessment, apparently became a neuropsychological assessment standard.

Table 1
Journals that published more than 4 articles about WAIS-III, according to the year of publication

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	**T0TAL**
Clinical Neuropsychologist	1	1	4	2	4	4	5	3	3	2	3	4					**36**
J Cl Exp Neuropsychology			1			1	6	4	4	4	2		3				**25**
Applied Neuropsychology		1	1	1	1		2			4	4	7		2	1		**24**
Psychological Assessment		2	5	1	1	1	3		2	1				1			**17**
Intelligence				1	2	1			4	1		1	1				**11**
Int Journal of Neuroscience		1	1	1	2		1	1				2					**9**
Journal of Clinical Psychology			1	1		2		1	1	1							**7**
… others with 4 or less articles	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	**97**
	1	**6**	**15**	**12**	**14**	**13**	**20**	**16**	**22**	**25**	**21**	**20**	**18**	**8**	**10**	**5**	**226**

Next, the reading and rating each item in accordance with its primary objective allowed a finding of 23 articles with word WAIS-III mentioned in the article but with no empirical WAIS-III data, 28 theoretical and/or no sample articles, 13 articles about the short-forms, 46 articles with standardization and/or technical manual samples, 28 articles

focused on other tests (e.g., validation of other tests/tasks), and 88 articles with various kinds of samples and empirical data.

From the 23 articles somehow had the word WAIS-III on the text, that made them selected by the database, but the article didn't give any WAIS-III data, 10 focused on other WAIS versions or other Wechsler Scales (Crum, 2000; McPherson et al, 2000; Ryan et al, 2000; McCarthy et al, 2003; Saklofske et al, 2003; Hawkins & Tulsky, 2004; Tulsky, 2004; Lucas et al, 2005; Ryan et al, 2005; Herreras, 2010), 10 focused on other tests (Tishler et al, 2006; Williams & Donovick, 2008; Velassaris et al, 2009; Rabin et al, 2008; Garcia-Molina et al, 2010; Herreras, 2010; Vilaseca et al, 2010, Juncos et al, 2011; Theodore et al, 2012; Tseng et al, 2013), and finally 3 papers had nothing to do with Wechsler Scales nor related tests (Roid et al, 2005; Karson, 2004, & Berry, 2008).

The 28 theoretical articles and/or articles with no sample could be subdivided in groups. Three articles were books reviews (Gregory, 2001; Donders, 2004; Larabee, 2004). Some were focused on the revision of the test and corrected norms (Nell, 1999; Okasaki & Sue, 2000; Tulsky & Ledbetter, 2000; Holdnack et al, 2004; Walker et al, 2009; Shuttleworth-Edwards, 2012), Flynn effect (Russell, 2007; Flynn, 2009), and index scores (Longman, 2004, 2005). Eight articles were focused on intellectual disabilities (Charter, 2003; Frumkin, 2006; Crawford et al, 2007; Whitaker, 2008; Suen & Greenspan, 2009a, 2009b; Escobedo & Hollingworth, 2009; Brooks et al, 2009). The rest of the articles focused on neuropsychological assessment (Herrera, 2008; Crawford & Gaithwaite, 2009), short-form (Crawford et al, 2008), malingering (Mittenberg et al, 2002), specific subtests (Shuttleworth-Edwards, 2002; van Ommem, 2005), and gender effect (Molenaar et al, 2009).

There were 13 articles that focused on different ways of short-forms for different kinds of population (Pilgrim et al, 1999; Ryan et al, 1999; Ryan & Ward, 1999; Axelrod & Ryan, 2000, Schopp et al, 2001; Donders & Axelrod, 2002; Kulas & Axelrod, 2002; Clara & Huynh, 2003; Alley et al, 2007; Christensen et al, 2007; Lange et al, 2007; Dura et al, 2010). Among these articles there were several forms to abbreviate the WAIS-III: the most common way was to reduce the number of subtests (we found versions with 9, 7, 4 and 2 subtests), the other way was to reduce the number of items per subtest (we found at least three ways to select items). The only study that compared these two ways to abbreviate the WAIS-III (Kulas & Axelrod, 2002) gave the primacy to the reduced subtest form (SF-7) over the reduced-item form (Staz-Mogel SF).

There were 46 articles based on the standardization or clinical samples described in the technical manual. Out of these 46 studies, we found five that concerned the clinical field trial samples, all with English speaking samples (Hawkins, 1998; Wilde et al, 2004; Schoenberg et al, 2003; Schoenberg et al, 2006; Lange & Chelune, 2007). In fact, only 8 out of these 46 papers were made with non-english speaking samples (Gregoire, 2001; Colom et al, 2002; Juan-Espinosa et al, 2002; Dolan et al, 2006; Renteria et al, 2008; Grieve & van Eeden, 2010; Roivainen, 2010; Golay & Lecerf, 2011).

The remaining of these 46 studies used samples with English-speaking samples from United States of America, Canada, Australia or United Kingdom and were focused on sampling or updating norms (Bowden et al, 2003; Wycherley et al, 2005), demographic variables effects (Kaufman, 2000, 2001; Dori & Chelune, 2004; Lange, Chelune et al, 2006; Saklosfke et al, 2008), factor analysis (Caruso & Cliff, 1999; Saklosfke et al, 2000; Ward et al, 2000; Tulsky & Price, 2003; Taub et al, 2004; Bowden et al, 2006; Bowden et al, 2007; Lange, 2007), *g* and General Ability Index (Tulsky et al, 2001; Lange et al, 2005; Saklosfke et al, 2005; Gignac, 2006a; Gignac, 2006b; Kane & Krenzer, 2006; Lange et al, 2006; Lange, Chelune & Tulsky, 2006), Oklahoma Premorbid Intelligence Estimate, OPIE-3 (Schoenberg et al, 2002, 2004, 2005), focused only on some subtests as Letter Number Sequencing (Tulsky & Zhu, 2000) or Digit Symbol (Joy et al, 2003; Ryan, Kreiner & Tree, 2008), and finally focused on other theoretical issues (Tulsky et al, 2000; Zhu & Tulsky, 2000; Reddon et al, 2004; Allen & Barchard, 2009).

There were 28 articles focused on other tests or tasks but showing WAIS-III data, these papers could be divided in two: 18 that used the core or the whole battery (Martin et al, 2000; Bell et al, 2001; Devaraju-Backhaus et al, 2001; Lassiter et al, 2001; Titus et al, 2002; Loring et al, 2002; Mathias et al, 2007; Barker-Collo et al, 2008; Ford et al, 2008; Forn et al, 2008; Green et al, 2008; O'Hara et al, 2008; Wilbur et al, 2008; Cioe et al, 2010; Misdraji & Gass, 2010; Barker-Collo et al, 2011; Olivar-Parra et al, 2011; Wieland et al, 2012) *versus* 10 that used only some subtests (Carey et al, 2004; Fisher & Rose, 2005; Kilgore et al, 2005; O'Hora et al, 2005; Scott et al, 2006; Zook et al, 2006; Esperanza, 2007; Barreyro et al, 2009; Haatveit et al, 2010; Cabrera et al, 2011).

Finally, 88 articles had various kinds of samples. We decided to divide them again in two groups: those which used the core or the whole battery (n=47) and those which used only some subtests (n=41), as summarized in table 2.

Table 2.

Articles using the whole WAIS-III or some subtests with various kinds of samples

	The whole WAIS-III was used	**Only some subtests were used**
Neurological samples	Martin et al (2002) – Epilepsy Lange & Chelune (2006) – Alzheimer's Disease (AD) Moyle et al (2007) – Phenilketonuria Ryan et al (2009) – lateralized lesion Murayama et al (2010) – Mild Cognitive Impairment Arreguin-Gonzalez et al (2011) – Cerebellar tumors Li et al (2012) – AD and Mild Cognitive Impairment **Only Traumatic Brain Injury (TBI) samples:** Fisher et al (2000) Axelrod et al (2001) Axelrod et al (2002) Van der Heidjen & Donders (2003) Langeluddecke & Lucas (2003) Langeluddecke & Lucas (2004) Strong et al (2005) Greve et al (2008) Blake et al (2009) Walker et al (2010)	Dugbartey et al (1999) – Matrix Reasoning Bowler et al (2001) – PSI+WMI subtests Earnst et al (2001) – WMI subtests Wilde & Strauss (2002) – Digit Span Costello & Connolly (2005) – Picture Arrangement Stubberud et al (2007) – Letter Number Sequencing Tranel et al (2008) – Matrix Reasoning Dean et al (2009) – Vocabulary and Digit Span Fucetola et al (2009) – Block Design + Matrix Reasoning + Picture Arrangement Karzmark (2009) – Arithmetic Introzzi et al (2010) – Matrix Reasoning Blanco-Rojas et al (2013) – Digit Span **Only TBI samples:** Kennedy et al (2003) – PSI+WMI subtests Noe et al (2010) – WMI subtests
Psychiatric and neuropsychiatric samples	Ryan et al (2002) – mixed sample Basso et al (2002) – mixed sample Miller et al (2004) – mixed sample Gorlyn et al (2006) – Major Depression Iverson et al (2006) – mixed sample Ryan et al (2006) – mixed sample Ryan et al (2007) – Substance Abuse Disorders Yao et al (2007) – Schizophrenia Glass et al (2009) – mixed sample Lin et al (2010) – substance abuse Lin et al (2012) – Schizophrenia Shan et al (2013) – schizophrenia	Kreiner & Ryan (2001) – Digit Symbol Coding Zakzanis et al (2003) – Vocabulary O'Bryan and O'Jile (2004) – Vocabulary Ditmann et al (2007) – Letter Number Sequencing Glass et al (2007) – Digit Symbol Tokley & Kemps (2007) – Object Assembly Pollice et al (2010) – Digit Span Bossman et al (2012) – Digit Span Bouso et al (2012) – Letter Number Sequencing
Educational samples	Jones et al (2006) – Low IQ sample Bigler et al (2007) – Autism Fitzgerald et al (2007) – Learning Disabilities Graue et al (2007) – Mental Retardation Hayes et al (2007) – Intellectual disability in prison Spinks et al (2007) – School achievement Wierzbicki et al (2007) – Learning and Attention Spek et al (2008) – Asperger Syndrome Whitaker and Wood (2008) – Learning Disability Tirri et al (2009) – Mathematically Gifted Students Copet et al (2010) – Prader-Willi syndrome Gordon et al (2010) – Special education students Nunes et al (2013) – Williams Syndrome	Stearns et al (2004) – WMI subtests Cheung et al (2012) – Vocabulary, Similarities, Picture Completion and Block Design
Research samples (i.e., volunteers with no clinical diagnosis and/or students)	Abad et al (2003) – University students Shuttleworth-Edwards et al (2004) – South Africa Van der Sluis et al (2006) – gender groups Greenaway et al (2009) – MOANS Davis et al (2011) – university students	Jung et al (2000) –Comprehension, Object Assembly and Picture Arrangement Mix and Crews (2002) – Block Design + Digit Symbol Lemay et al (2004) – Letter Number Sequencing Shuttleworth-Edwards et al (2004b) – Digit Symbol Hopko et al (2005) – 5 performance subtests Cannon et al (2006) – WMI+PSI subtests Etherthon et al (2006) – PSI subtests Schwarz et al (2006) – Digit Span + Vocabulary + Digit Symbol Coding + Symbol Search Cottone et al (2007) – Comprehension + Similarities Ryan and Tree (2007) – 5 performance subtests Rozencwajg & Bertoux (2008) – Similarities Ryan et al (2008) – supplementary and optional subtests Cannon et al (2009) – WMI+PSI subtests Hill et al (2010) – WMI subtests Davis and Pierson (2012) – Digit Symbol Coding Holtzer et al (2012) – Vocabulary + Digit Symbol

Legend: WMI = Working Memory Index and PSI = Processing Speed Index

In sum, from the big pool of 226 papers on WAIS-III, the two most popular focus were studies with various kinds of samples on WAIS-III (n=88, 39%) and technical/psychometric studies made with the standardization samples (n=46, 20%). We

were especially interested in these 88 "sample" studies, and we were surprised that only 15 papers included educational samples; against the 21 university and/or community samples, the 21 psychiatric or neuropsychiatric samples and the 31 neurological samples. We also noticed that slightly more than half of these 88 papers used the whole or the core battery (n=47) and the remaining used only one or a few subtests (n=41). We think this reflects the actual clinical use of the WAIS-III, as we all know that there are several environments where only a few subtests are used.

Last but not the least, looking in some detail to the last column of table 2, we find out that the most popular subtests studied in these papers seemed to be Processing Speed Index's subtests (Digit Symbol Coding and Symbol Search), Working Memory Index's subtests (Digit Span, Arithmetic and LNS) and Matrix Reasoning (new subtest in this battery). Once again, these issues are very important in neuropsychological assessment, because they enable levels of analysis focused on more specific neurocognitive functions.

(2) Criteria used for the selection of neurological samples

Next, we wanted to know the criteria used to select the more frequently studied neurological samples. It didn't matter if the study was based (1) on the core/whole WAIS-III, (2) on some subtests from the battery, (3) on WAIS-III short-forms or (4) on the validation/study of other tests. So we went back to the 226 articles and we selected all that had Traumatic Brain Injury (TBI) samples (Table 3) and "mixed neurological" samples (Table 4).

As shown in Table 3, there were 19 articles with TBI samples. A large number of articles had mild TBI subsample, but most the articles focus on moderate, moderate-severe or severe TBI. Near half of the articles didn't have a control group without TBI, 5 articles have a subsample of the standardization sample, and 4 articles had control samples with other clinical etiologies. Although most of the articles described the sample in detail (e.g., loss of consciousness, post-traumatic amnesia, time elapsed since injury), there were still 6 articles that didn't categorize their samples in severity of the TBI.

Table 3.
TBI samples: frequency of different severities by samples

		MTBI	M-MoTBI	MoTBI	Mo-STBI	STBI	ESTBI	**Total TBI**	**Controls with no TBI**
1	Fisher et al (2000)	23			22			**45**	**45 matched from the standardization sample**
	Axelrod et al (2001)		46					**46**	**n.r.**
	Axelrod et al (2002)		51					**51**	**n.r.**
	Van der Heidjen and Donders (2003)	78			88			**166**	**n.r.**
	Langeluddecke and Lucas (2003)			35		74	41	**150**	**50 matched from the standardization sample**
	Langeluddecke and Lucas (2004)			35		74	41	**150**	**50 matched from the standardization sample**
	Miller et al (2004)	15		3		10		**27**	**30 alcohol abuse + 43 polysubstance abuse**
	Strong et al (2005)	53			47			**100**	**100 matched from the standardization sample**
	Greve et al (2008)	127			84			**211**	**93 other neurological diagnosis**
	Blake et al (2009)	18		8		31		**57**	**61 pseudoneurologic controls**
	Walker et al (2010)							**196**	**n.r.**
2	Kennedy et al (2003)	26		20		20		**66**	**n.r.**
	Noe et al (2010)							**239**	**n.r.**
3	Schopp et al (2001)							**118**	**n.r.**
	Donders and Axelrod (2002)	41			51			**100**	**100 matched from the standardization sample**
	Reid-Arndt et al (2011)							**176**	**n.r.**
4	Martin and Donders (2000)	29			31			**53**	**n.r.**
	Green et al (2008)							**24**	**n.r.**
	Wilbur et al (2008)							**42**	**42 Learning Disabilities + 42 Emotional Diagnosis**

Notes: n.r. = not reported;
MTBI = Mild Traumatic Brain Injury (TBI); M-MoTBI = Mild to moderate TBI; MoTBI = Moderate TBI; Mo-STBI = Moderate to severe TBI; STBI = Severe TBI, and ESTBI = Extremely severe TBI.
1 = used 11, 13 or 14 subtests to study the TBI sample; 2 = used some subtests to study the TBI sample; 3 = short-form studies, and 4 = focus on other tests.

As it can be seen on Table 4, there were 20 articles that had mixed neurologic and/or neuropsychiatric samples. Only two of these articles described the subjects according to brain injury location: different locations of the prefrontal cortex but only matrix reasoning subtest (Tranel et al, 2008), and right *versus* left hemisphere injuries in the whole battery performance (Ryan t al, 2009). The remaining of the articles are mainly large series of accumulations of patients with various kinds of etiologies that vary a lot in age and gender.

Table 4.
Mixed neurological/neuropsychiatric samples:
Frequencies of the main etiologies and means and SD of demographic variables

	n	Neurologic diagnosis (n)	Psychiatric Diagnosis (n)	Unspecified clinical diagnosis or others (n)	Demographic variables by subsample
Basso et al (2002) – 3 and 6 months interval	51			51 patients screened for neurological and psychiatric disease	Age: 24.6 Education: 14.4 Gender: reported Ethnicity: reported
Ryan et al (2002) - Low *versus* high scatter groups	40 + 40	2/3 dementia	9/7 nonpsychotic 2/1 psychotic 21/20 substance abuse	5/3 brain injury 1/6 medical disorders	n= 40 / 40 Age: 50.18 SD 14.32 / 50.95 SD 12.92 Education: 13.12 SD 2.0 / 13.02 SD 2.12 Male: 100% / 100% Ethnicity: reported Handedness: reported
Miller et al (2004) – TBI *versus* Alcohol *versus* Polysubstance	100	27 head trauma	30 alcohol abuse 43 polysusbstance abuse		n= 27 / 30 / 43 Age: 33.44 SD 10.35 / 50.90 SD 11.37 / 42.40 SD 5.85 Education: 12.04 SD 1.7 / 11.93 SD 1.91 / 12.79 SD 1.54 Gender: 15M 12F / 29M 1F / 42M 1F Ethnicity: reported
Iverson et al (2006) – neuropsychiatric *versus* forensic groups	40 + 60		26 schizophrenia spectrum disorder 16 substance abuse 5 bipolar disorder	40 neuropsychiatric patients 13 undiagnosed forensic	n= 40 / 60 Age: 45.5 SD 11.4 / 36.3 SD 13.1 Education: 11.5 SD 2.9/ 10.2 SD 2.4 Male: 62,5%/85% Ethnicity: reported
Ryan et al (2006)	174	86 TBI 40 stroke 16 dementia 15 seizure disorders 5 tumor 2 meningitis 2 encephalitis 2 multiple sclerosis 2 encephalopathy			Age: 49.19 SD 15.33 Education:12.57 SD2.78 Gender: 116M 58F Ethnicity: reported Control group: standardization sample (n=2450)
Ryan et al (2009) – left *versus* right hemisphere injury	36	20 vascular 14 TBI 1 Tumor 1 Tumor+TBI			n= 20 / 16 Age: 46.25 SD 17.42 / 47.86 SD 16.83 Education:12.17 SD2.87 / 12.27 SD2.46
Dugbartey et al (1999) – study 1	41	8 TBI 6 neurotoxin exposure 2 cerebral neoplasm 2 subarachnoid hemorrhage	5 unipolar depression 4 alcoholism	3 asymptomatic HIV 11 mixed diagnosis	Age: 38.2 SD 12.1 Education: 12.5 SD 2.81 Gender: 22M 19F Ethnicity: reported Handedness: reported
Dugbartey et al (1999) – study 2	14	2 seizure disorders 1 cerebrovascular 1 cerebral neoplasm	1 depression 1 schizophrenia	4 short-term memory loss 2 cardiac disease 1 hypertension 1 chronic renal disease	All immigrants Age: 55.56 SD 17.9 Education: 4.5 SD 4.3 Gender: 7M 7F Ethnicity reported
Wilde and Strauss (2002)	44	35 TBI		9 various etiologies	Age: 37.1 SD 13.9 Education: 12.4 SD 2.0 Gender: 26M 18F
Costello and Conolly (2005)	400			4x100 archival samples of two laboratories (no diagnosis)	Age + gender: reported Education: n.r. Ethnicity: reported
Tranel et al (2008)	160	101 cerebrovascular 56 surgical resection* 3 herpes simples encephalitis			Demographics reported for each of the four subsamples created.
Karzmark (2009)	118	23 dementia 18 TBI 15 cerebrovascular 8 developmental 6 anoxia 4 tumor 7 others		25 psychiatric disorder 12 no diagnosis	Age: 47.2 SD 16.1 Education: 15.0 SD 2.9 Gender: 77M 41F Ethnicity: reported
Bossman et al (2012)	92	55.4% ischaemic stroke 16.3% haemorragic str. 7.6% Subarachnoid haemorrhage 5.4% post-anoxic			Age: 55.6 SD14.6 Educ: 38.9% high school Gender: 48M 34F Consecutive inpatients

			12% TBI 1.1% brain abscess 2.2% brain tumor			
3	Pilgrim et al (1999)	111	10.8% seizure disorder 9.9% TBI 9.9% vascular 3.6% subcortical dementia 1.8% hydrocephalus 1.8% encephalitis 2% brain tumor 9% Parkinson's disease		21.6% mental health 18.9% motor vehicle accident 4.5% learning disability 4.5% developmental 1.8% systemic lupus e. 1.8% electrical injury 6.3% unspecified or multiple etiologies	Age: 40.49 SD 18.04 Education:11.82 SD2.33 Gender: 65M 46F Ethnicity: reported handedness:85,6% right
	Axelrod and Ryan (2000)	278			278 patients referred for neuropsychological evaluation	Age: 51.8 SD 15.1 Education: 12.3 SD 2.3 Gender: 270M 8F Handedness: 90% right Ethnicity: reported
	Kulas and Axelrod (2002)	150	3% stroke 8% Alzheimer's disease 7% seizure disorder 3%multi-infart dementia 1% aneurism 10% TBI 1% Parkinson's disease 1% multiple sclerosis	19% substance abuse 14% mood disorder 11% schizophrenia 9% anxiety	6% free from neurologic or psychiatric condition	Age: 53.5 SD 14.2 Education: 12.2 SD 2.3 Gender: 95% male Handedness: 91% right Ethnicity: reported
	Lange et al (2007)	100		26 schizophrenia spectrum disorder 16 substance abuse 5 bipolar disorder	40 neuropsychiatric patients 13 undiagnosed forensic	See above Iverson et al (2006)
4	Devaru-Backhaus et al (2001)	85			22 psychiatric disorder 54 neurological disorder 9 no DSM-IV or neurological disorder	Age: 38.73 SD 16.54 Education: 13.07 SD 2.6 Gender: 40M 45F Handedness:86,3%right Ethnicity: reported
	Fisher and Rose (2005)	32	18 TBI 2 cerebral hemorrhage 2 epilepsy 2 multiple sclerosis 1 cerebral palsy 1 cerebrovascular accident 1 Alzheimer's disease 1 encephalitis 1 hydrocephalus		3 unspecified neurologic problem	Age: 40 SD 13.38 Education: 12 SD 2.17 Gender: 18M 14F There were 2 other groups: 64 healthy volunteers subdivided in 32 controls and 32 simulators of memory impairment.
	Misdraji and Gass (2010)	192			192 consecutive neuropsychological referrals	Age: 59.3 SD 14.5 Education: 13.2 SD 2.2 Gender: 180M 12F

Notes: n.r. = not reported; 1 = used the core subtests; 2 = used some subtests; 3 = short-form studies, and 4 = focus on other tests.
* 56 surgical resection = 23 benign tumor, 9 hematoma, 16 anterior temporal lobectomy for pharmacoresistent epilepsy, and 8 arteriovenous malformation.

(3) Is there a specific profile in acquired brain injury?

To answer this final question we focused on the 88 empirical articles with samples summarized in Table 2. From these articles, we first selected the 48 studies that had clinical samples (neurological, psychiatric or mixed neuropsychiatric). We then decided to pay special attention only to the studies that used 11, 13 or 14 subtests from the battery, and that gave us data about IQs, Indexes or subtests (middle column of table 2). We called these studies, articles that "used the whole battery". We ended up with 29 clinical studies that used the whole/core battery and we sorted these studies by the samples: 6 mixed neurologic/neuropsychiatric (Table 5), 10 TBI (Table 6), 7 other neurologic etiologies (Table 7), and 6 psychiatric samples (Table 8).

We noticed that the six mixed neurological/neuropsychiatric samples that used the whole battery (Table 5), when characterized by etiology, were mainly addressing head trauma (i.e., TBI) or substance abuse disorders. These samples were all from North America, all reported a majority of Caucasian ethnicity, but only two studies reported handedness (Ryan et al, 2002; Glass et al, 2009). The samples were mainly of men with low-average or average IQ, mean aged from 40 to 50 years old (exception to the head trauma group described by Miller et al, 2004), and all had a mean education level of high school. Only one study had a control group of people with no clinical diagnosis; that group was the 2450 individuals from the US standardization sample (Ryan et al, 2006). Against our expectations, only one of these studies (Ryan et al 2006) looked for a clinical profile and didn´t find any difference in the inter-subtest scatter among brain injured patients compared to normal controls.

In what concerns the TBI samples (Table 6), 4 out of 10 articles selected concluded that the Processing Speed Index (PSI) is lower in all TBI samples with chronic and at least mild-to-moderate severity (Fisher et al, 2000; Axelrod et al, 2001; Axelrod et al, 2002; Langeluddecke et al, 2003). These results support the clinical trials (Hawkins, 1998), where the PSI was particularly sensitive to brain dysfunction; but the same results were obtained with Phenilketonuria patients (Moyle et al, 2007 – see Table 7) and Depression samples as well (Gorlyn et al, 2006 – see Table 8). So, although a low PSI is a good indicator of a TBI, it is also suggestive of other brain dysfunctions/diseases.

The other six articles with TBI samples were not looking for a clinical profile. One was trying to replicate the four-factor model (van der Heidjen & Donders, 2002), one discusses two methods for estimating premorbid intelligence (Langeluddecke & Lucas, 2004), two were focused on corrected norms (Strong et al, 2005; Blake et al, 2009), one focus on Australian cultural diversity (Walker et al, 2010) and, finally one was focused on malingering (Greve et al, 2008).

Table 5

Descriptive analysis (Means and Standard Deviations) and main conclusions from the mixed neurological/neuropsychiatric samples

	Etiology	Age	Education	Gender	VIQ	PIQ	FSIQ	VCI	POI	WMI	PSI	Subtests	Main conclusions
Basso et al (2002)	51 patients screened for neurological and psychiatric disease:												
	- baseline	n.r.	n.r.	n.r.	111.0 (11.5)	105.4 (12.5)	109.4 (11.6)	111.5 (11.9)	106.1 (14.1)	106.9 (12.4)	109.3 (13.0)	n.r.	All IQs and indexes, except WMI, improved significantly from baseline to 3- or 6-months reevaluation
	- retest	n.r.	n.r.	n.r.	114.8 (11.5)	116.0 (14.4)	115.04 (12.1)	115.8 (12.3)	114.4 (14.1)	108.6 (13.1)	116.4 (14.5)	n.r.	
Ryan et al (2002)	40 low scatter group*	50.18 (14.32)	13.12 (2.00)	40M	101.15 (10.78)	98.38 (10.56)	99.88 (10.47)	n.r.	n.r.	n.r.	n.r.	11 subtests reported	When differences in IQ are controlled, the intersubtest scatter does not predict memory performance
	40 high scatter group**	50.95 (12.92)	13.02 (2.12)	40M	100.38 (11.83)	99.18 (13.26)	99.78 (10.30)	n.r.	n.r.	n.r.	n.r.	11 subtests reported	
Miller et al (2004)	30 alcohol abuse	50.90 (11,37)	11.93 (1.91)	29M 1F	93.70 (10.94)	92.17 (10.13)	92.60 (10.03)	n.r.	n.r.	n.r.	n.r.	Vocabulary + Digit Span	Vocabulary – Digit Span score has 99% overall accuracy detecting malingering
	43 polysubstance abuse	42.40 (5.85)	12.79 (1.54)	42M 1F	98.51 (14.11)	97.09 (14.17)	99.40 (14.73)	n.r.	n.r.	n.r.	n.r.	Vocabulary + Digit Span	
	27 head trauma	33.44 (10.35)	12.04 (1.70)	15M 12F	93.37 (11.44)	93.52 (8.17)	93.04 (9.11)	n.r.	n.r.	n.r.	n.r.	Vocabulary + Digit Span	
Iverson et al (2006)	40 neuropsychiatric + 60 forensic psychiatric:												
	- American norms	n.r.	n.r.	n.r.	84.9 (14.3)	81.4 (14.8)	82.0 (14.6)	86.9 (15.5)	86.1 (15.3)	82.5 (16.2)	76.6 (13.2)	11 subtests reported	Significantly lower scores on all IQs, Indices, and subtest scores will be calculated when using the Canadian *versus* the American norms
	- Canadian norms	n.r.	n.r.	n.r.	82.0 (12.8)	76.5 (14.9)	78.1 (13.0)	84.3 (13.4)	81.3 (14.6)	79.9 (14.2)	73.8 (14.3)	11 subtests reported	
Ryan et al (2006)	174 mixed neurologic patients***	49.19 (15.33)	12.57 (2.78)	116M 58F	89.06 (16.36)	86.17 (17.12)	88.45 (17.78)	89.82 (16.54)	89.99 (17.26)	84.84 (16.34)	79.51 (13.45)	13 subtests reported	Inter-subtest scatter among brain-damaged patients is no greater than among normal persons
Glass et al (2009)	82 polysubstance abuse + 53 alcohol abuse	47.16 (9.19)	12.55 (1.58)	135M; 0F	n.r.	n.r.	92.10 (13.73)	94.39 (13.61)	93.51 (14.27)	92.57 (14.30)	86.46 (11.99)	n.r.	GAI and FSIQ were highly correlated

* 9 nonpsychotic psychiatric disorders; 2 psychotic psychiatric disorders; 5 neurological disorders involving brain; 1 medical disorder; 21 substance abuse disorders, and 2 dementia

** 7 nonpsychotic psychiatric disorders; 1 psychotic psychiatric disorders; 3 neurological disorders involving brain; 6 medical disorder; 20 substance abuse disorders, and 3 dementia

*** 86 TBI; 40 stroke; 16 dementia; 15 seizure disorders; 5 tumors; 2 meningitis; 2 encephalitis; 2 multiple sclerosis; 2 anoxia; 2 hydrocephalus, and 1 each cardiac and hepatic encephalopathy

Note: n.r. = not reported; VIQ = Verbal IQ; PIQ = Performance IQ; FSIQ = Full Scale IQ; VCI = Verbal Comprehension Index; POI = Perceptual Organization Index; WMI = Working Memory Index, and PSI = Processing Speed Index.

Table 6 - Descriptive analysis (Means and Standard Deviations) and main conclusions from the TBI samples

	TBI severity	Age	Education	Gender	Time elapsed	VIQ	PIQ	FSIQ	VCI	POI	WMI	PSI	subtests	main conclusions
Fisher et al (2000)	45 controls from standardization sample	32.53 (9.93)	12.96 (1.94)	n.r.	n.a.	100.0 (13.8)	101.7 (14.6)	100.8 (14.0)	99.2 (14.6)	102.4 (14.3)	100.6 (16.4)	99.6 (14.0)	n.r.	No IQ or index score will help discriminate mild TBI patients from normal controls. IQ and index scores were lower for moderate-severe TBI, even when controlling for education level; PSI was particularly low
	23 mild TBI	35.73 (11.33)	12.87 (2.53)	12M 11F	431 days (367.9)	96.3 (12.7)	100.0 (13.8)	98.0 (13.1)	95.8 (16.0)	104.6 (15.4)	96.1 (11.2)	95.3 (12.2)	n.r.	
	22 moderate-severe TBI	26.9 (5.9)	13.32 (1.67)	14M 8F	n.r.	89.6 (12.4)	84.5 (13.8)	86.5 (10.9)	89.6 (12.7)	92.1 (15.0)	89.8 (13.1)	73.4 (10.7)	n.r.	
Axelrod et al (2001)	46 at least mild-moderate TBI	33.5 (13.3)	12.6 (2.3)	32M 13F	4.9 months (5.8)	88.5 (14.7)	85.1 (16.0)	85.6 (15.4)	88.2 (15.0)	88.1 (16.0)	90.4 (11.9)	79.6 (11.7)	n.r.	PSI was more sensitive (but not specific) to brain injury than other WAIS-III composites
	22 controls from standardization sample	n.r.	n.r.	n.r.	n.a.	89.6 (12.4)	84.5 (13.8)	86.5 (10.9)	89.6 (12.7)	92.1 (15.0)	89.8 (13.1)	73.4 (10.7)	n.r.	
Axelrod et al (2002)	51 at least mild-moderate TBI	33.9 (13.5)	12.5 (2.3)	35M 16F	4.2 months (5.0)	90.5 (15.5)	86.4 (15.8)	87.9 (15.8)	90.4 (16.0)	89.8 (16.1)	90.8 (12.7)	81.0 (1.9)	n.r.	PSI was significantly lower than other indexes. Tables of frequencies differences
van der Heidjen and Donders(2003)	78 mild TBI + 88 moderate-severe TBI	33.14 (14.84)	12.64 (1.93)	105M 61F	92.14 days (69.38)	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	A four-factor model, similar to the technical manual, provided the best fit to the clinical data
Langeluddecke and Lucas (2003)	50 controls from standardization sample	38.3 (20.8)	12.7 (2.9)	24M 26F	n.a.	104.9 (16.0)	104.08 (15.3)	105.4 (16.3)	105.7 (15.7)	104.7 (15.3)	102.8 (15.5)	102.4 (16.6)	13 subtests reported	Subtests scores are discussed.
	35 Moderate TBI	35.6 (13.8)	11.9 (2.5)	24M 12F	32.1 months (19.7)	102.1 (14.7)	100.9 (14.4)	101.7 (14.4)	103.0 (15.5)	104.07 (15.4)	101.9 (14.4)	93.1 (12.6)	13 subtests reported	PSI scores were lower by an average of 9 points.
	74 Severe-Very Severe TBI	31.5 (11.3)	11.6 (2.4)	53M 22F	34.1 months (24.6)	94.5 (14.6)	91.7 (13.6)	92.7 (14.3)	95.2 (15.0)	95.6 (14.4)	94.4 (14.1)	88.1 (12.9)	13 subtests reported	PSI scores were lower by an average of 14 points, and FSIQ an average approximately 9 points.
	41 Extremely Severe TBI	36.6 (13.2)	11.3 (2.6)	29M 15F	33.9 months (23.1)	89.7 (15.1)	86.4 (12.5)	87.3 (14.3)	90.5 (14.5)	91.2 (12.7)	90.1 (16.9)	80.1 (13.0)	13 subtests reported	PSI scores were lower by an average of 22 points, and FSIQ an average approximately 16 points.
Langeluddecke and Lucas (2004)	same as Langeluddecke and Lucas (2003)	see above	see above	see above	see above	see above	see above	see above	see above	see above	see above	see above	n.r.	Discusses two methods for estimating premorbid intelligence
Strong et al (2005)	53 mild + 47 moderate-severe TBI	33.92 (15.43)	12.60 (2.08)	66M 34F	102.43 days (76.67)	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	Demographically corrected norms are not clearly better or worse than the conventional age-corrected norms
	100 controls from standardization sample	34.29 (15.94)	12.53 (2.181)	66M 34F	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	
Greve et al (2008)	93 general clinical (other diagnosis)	57.0 (16.1)	14.1 (2.6)	48M 45F	n.r.	95.0 (15.5)	90.4 (14.8)	92.4 (14.7)	n.r.	n.r.	n.r.	n.r.	n.r.	VIQ accurately differentiated malingering from non-malingering patients regardless of injury severity PIQ was only accurate in mild TBI and did not add increment validity to the VIQ
	127 mild TBI + 84 moderate-severe TBI	38.3 (13.6)	12.1 (3.1)	151M 60F	22.1 months (26.0)	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	
	87 TBI not-malingering	n.r.	n.r.	n.r.	n.r.	95.8 (15.5)	94.3 (17.2)	94.8 (16.5)	n.r.	n.r.	n.r.	n.r.	n.r.	
	68 TBI indeterminate malingering	n.r.	n.r.	n.r.	n.r.	87.9 (14.1)	88.1 (14.6)	87.2 (14.6)	n.r.	n.r.	n.r.	n.r.	n.r.	
	56 TBI malingering	n.r.	n.r.	n.r.	n.r.	75.6 (12.6)	77.9 (13.7)	74.5 (13.4)	n.r.	n.r.	n.r.	n.r.	n.r.	
Blake et al (2009)	18 mild + 8 moderate + 31 severe TBI	40.70 (16.90)	13.00 (1.94)	36M 21F	8.51 months (25.65)	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	11 subtests reported	The corrected norms are no more or less beneficial than traditional age-corrected norms for neurodiagnostic purposes
	61 controls (pseudoneurologic group)	45.46 (13.13)	13.23 (2.62)	17M 44F	16.92 months (18.57)	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	11 subtests reported	

	130 moderate-severe TBI - english-australian	30.7 (12.0)	11.0 (2.2)	98M 32F	28.2 weeks (21.8)	93.3 (13.8)	90.9 (13.7)	n.r.	92.9 (14.3)	94.3 (14.0)	93.9 (14.1)	85.6 (12.2)	11 subtests reported	The English-educated culturally and linguistically diverse group performed lower than the English-speaking background group on some verbal WAIS-III measures
Walker et al (2010)	33 moderate-severe TBI - "english country"	27.2 (10.6)	11.0 (1.8)	27M 6F	25.3 weeks (20.4)	87.2 (13.0)	88.3 (13.0)	n.r.	87.5 (12.7)	92.3 (13.3)	88.1 (15.2)	82.9 (12.3)	11 subtests reported	
	33 moderate-severe TBI - "non english country"	43.9 (13.1)	10.8 (3.2)	27M 6F	25.7 weeks (17.9)	n.r.	79.0 (11.2)	n.r.	n.r.	81.8 (11.7)	n.r.	78.9 (11.8)	11 subtests reported	The non-English-educated diverse group performed lower than both groups on several WAIS-III measures

Note: n.r. = not reported; n.a. = not applicable; VIQ = Verbal IQ; PIQ = Performance IQ; FSIQ = Full Scale IQ; VCI = Verbal Comprehension Index; POI = Perceptual Organization Index; WMI = Working Memory Index, and PSI = Processing Speed Index.

Table 7.
Descriptive analysis (Means and Standard Deviations) and main conclusions from the other neurological samples

	Etiology	Age	Education	Gender	VIQ	PIQ	FSIQ	VCI	POI	WMI	PSI	subtests	main conclusions
Martin et al (2002)	42 unoperated-on adult patients with complex partial seizures	34.8 (11.3)	13.2 (2.6)	13M 29F	86.6 (16.1)	86.4 (14.6)	85.5 (15.9)	87.0 (14.6)	88.0 (15.1)	89.1 (17.6)	n.r.	11 subtests reported	Individual subtests for the WAIS-III were less reliable than the Index scores but still within very acceptable reliability ranges
	42 same sample, mean 7-month retesting interval	Same	same	same	86.4 (16.4)	89.5 (14.6)	86.9 (16.1)	87.6 (15.4)	90.8 (14.3)	87.6 (16.2)	n.r.	11 subtests reported	
Lange et al (2006)	34 patients with Alzheimer's type dementia	73.0 (7.2)	14.5 (2.9)	19M 15F	n.r.	n.r.	n.r.	93.2 (12.1)	85.1 (12.4)	n.r.	n.r.	n.r.	GAI-memory discrepancy differenciate patients with DAT from healthy participants, however failed to provide unique interpretive information beyond that which is gained from memory indexes alone
	34 controls matched from the standardization sample	72.9 (7.1)	14.2 (2.7)	19M 15F	n.r.	n.r.	n.r.	109.8 (15.4)	105.7 (12.4)	n.r.	n.r.	n.r.	
Moyle et al (2007)	12 Phenylketonuria (PKU) treated with a low-phenylalanine diet from birth	28.5 (3.3)	11.8 (0.5)	2M 10F	n.r.	n.r.	n.r.	105 (n.r.)	101 (n.r.)	103 (n.r.)	92 (n.r.)	n.r.	POI and PSI were significantly lower in the PKU group. Taken together with WMS-III and TMT scores, these results supported a profile of reduced information-processing speed
	12 controls (friends of PKU group)	29.2 (3.2)	12.2 (0.5)	Matched	n.r.	n.r.	n.r.	106 (n.r.)	115 (n.r.)	101 (n.r.)	106 (n.r.)	n.r.	
Ryan et al (2009)	20 left brain lesion (mixed etiology)	46.25 (17.42)	12.17 (2.87)	n.r.	86.70 (17.78)	87.45 (15.65)	n.r.	87.10 (17.04)	94.25 (15.84)	n.r.	n.r.	n.r.	Neither VIQ-PIQ nor VCI-POI discrepancy scores were effective in identifying lateralized brain damage.
	16 rigth brain lesion (mixed etiology)	47.86 (16.83)	12.27 (2.46)	n.r.	92.56 (16.48)	82.56 (15.58)	n.r.	90.95 (14.50)	86.06 (15.26)	n.r.	n.r.	n.r.	
Murayama et al (2010)	8 early Mild Cognitive Impairment (MCI)	70.5 (3.1)	14.6 (2.1)	5M 3F	127.1 (8.0)	120.3 (8.4)	126.5 (7.1)	121.1 (8.1)	n.r.	n.r.	n.r.	n.r.	The discrepancy between intelligence and memory scores combined with F-FDG PET findings would make it possible to diagnose early-stage amnestic MCI.
	10 MCI	68.8 (5.5)	13.8 (2.2)	3M 7F	113.9 (11.4)	105.8 (8.7)	111.4 (10.5)	107.6 (12.2)	n.r.	n.r.	n.r.	n.r.	
	6 controls	68.3 (4.7)	14.0 (1.8)	2M 4F	113.3 (10.2)	107.7 (9.5)	112.2 (10.5)	107.3 (7.6)	n.r.	n.r.	n.r.	n.r.	
Arreguin-Gonzalez et al (2011)	12 untreated cerebellar tumor	45 (1.3)	n.r.	8M 3F	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	A tumor in the cerebellum may cause substantially lower mean IQ.
Li et al (2012)	30 patients = = 18 Alzheimer's Disease + +12 Mild Cognitive Impairment	73.80 (8.26)	n.r.	8M 22F	82.74 (18.60)	78.04 (19.12)	79.00 (19.85)	n.r.	n.r.	n.r.	n.r.	14 subtests reposted	Z-scores of VSRAD were revealed to have close relation with many neuropsychological tests, especially ADAS-cog and subtest Information

Note: n.r. = not reported; VIQ = Verbal IQ; PIQ = Performance IQ; FSIQ = Full Scale IQ; VCI = Verbal Comprehension Index; POI = Perceptual Organization Index; WMI = Working Memory Index, and PSI = Processing Speed Index and VSRAD = voxel-based specific regional analysis system for Alzheimer's disease.

Table 8.
Descriptive analysis (Means and Standard Deviations) and main conclusions from the psychiatric samples

	Etiology	Age	Education	Gender	VIQ	PIQ	FSIQ	VCI	POI	WMI	PSI	subtests	main conclusions
Gorlyn et al (2006)	41 non-patients controls	33.80 (11.9)	16.49 (2.5)	20M 21F	118.3 (18.0)	115.1 (18.4)	118.4 (17.9)	120.5 (17.3)	113.4 (17.1)	109.8 (17.3)	110.0 (13.8)	11 subtests reported	Results suggest general intellectual performance in depression is best characterized by deficits in processing speed.
	81 major depression + 40 bipolar disorders	38.40 (12.0)	15.86 (2.4)	50M 71F	114.3 (14.2)	108.4 (17.0)	112.9 (15.2)	117.1 (14.0)	109.5 (16.5)	106.8 (14.8)	101.9 (15.5)	11 subtests reported	
Ryan et al (2007)	131 substance abuse disorders	47.16 (9.14)	12.59 (1.58)	132M 2F	n.r.	n.r.	92.37 (14.14)	n.r.	n.r.	n.r.	n.r.	n.r.	Case-by-case analyses demonstrated concordance rates of 99% for the IMI-GMI and IMI-DMI comparisons and 94% for the FSIQ-GMI and FSIQ-DMI contrasts
Yao et al (2007)	114 schizophrenia	32.5 (10.2)	10.5 (2.9)	60M 54F	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	The results of the present study with two Chinese mainland samples provide further support for the WAIS-III Chinese version four factor structure.
	114 controls from standardization sample	32.8 (10.3)	10.6 (3.2)	53M 61F	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	
Lin et al (2010)	34 methamphetamine-induced psychosis	28.7 (6.1)	10.4 (1.8)	28M 6F	84.3 (11.9)	81.9 (12.1)	82.3 (10.8)	85.5 (11.9)	84.7 (12.5)	85.4 (13.6)	78.5 (12.7)	13 subtests reported	Although methamphetamine-induced psychosis patients were younger, with shorter duration of substance misuse than alcoholic patients, their mentality had more severe deterioration.
	34 alcohol dependent	40.7 (7.3)	11.1 (2.8)	32M 2F	95.2 (11.3)	86.0 (13.8)	90.5 (12.0)	95.5 (11.0)	87.1 (14.5)	96.2 (13.1)	84.5 (15.0)	13 subtests reported	
Lin et al (2012)	120 schizophrenia	37.96 (9.86)	13.08 (2.84)	58M 62F	94.53 (17.08)	90.61 (16.84)	92.52 (15.63)	n.r.	n.r.	92.10 (17.57)	n.r.	5 subtests reported	Mismatch negativity deficits were found in Han Chinese schizophrenia patients. The multivariate approach combining biomarkers from different modalities such as electrophysiology and neuropsychology had a better diagnostic utility.
	76 healthy controls	36.25 (1.12)	15.73 (3.52)	30M 46F	112.67 (16.22)	113.06 (16.56)	112.25 (18.88)	n.r.	n.r.	112.14 (15.30)	n.r.	5 subtests reported	
Shan et al (2013)	106 schizophrenia	37.2 (10.0)	13.8 (2.7)	52M 54F	95.74 (16.76)	90.58 (18.05)	93.21 (16.15)	n.r.	n.r.	93.14 (17.66)	n.r.	5 subtests reported	The first diagnostic model for schizophrenia in subjects of Chinese ethnicity, using P50 sensory gating along with neuropsychological tests
	74 controls	36.2 (11.5)	15.3 (3.6)	31M 43F	113.0 (16.28)	113.5 (16.53)	114.1 (19.04)	n.r.	n.r.	112.5 (15.34)	n.r.	5 subtests reported	

Note: n.r. = not reported; VIQ = Verbal IQ; PIQ = Performance IQ; FSIQ = Full Scale IQ; VCI = Verbal Comprehension Index; POI = Perceptual Organization Index; WMI = Working Memory Index; PSI = Processing Speed Index; DMI = Delayed Memory Index, and GMI = General Memory Index

Comparing the TBI samples (Table 6) with other mixed neuropsychiatric samples (Table 5), we noticed that TBI samples are a decade younger (TBI mean age is most of the times between 30 and 40); education level is apparently the same as other neurologic samples (high-school), but the disproportion of male *versus* female is higher in TBI samples. Although there were some studies in a post-acute phase for TBI samples (van der Heidjen & Donders, 2003; Strong et al, 2005; Walker et al, 2010), the majority of TBI studies focused on chronic patients. For the mixed neuropsychiatric samples, there is no report about the time elapsed since diagnosis/injury.

In sum, from the 29 "clinical samples" papers selected, only 9 had a goal equal or similar to looking for a clinical profile in the WAIS-III (Fisher et al, 2000; Axelrod et al, 2001; Axelrod et al, 2002; Langeluddecke et al, 2003; Gorlyn et al 2006; Ryan et al, 2006; Moyle et al, 2007; Ryan et al, 2009; Arreguin-Gonzalez et al, 2011). Further, based on these studies, the most robust conclusion we came to was that the PSI is sensitive to many clinical groups, including the Traumatic Brain Injury (TBI). Altough the WAIS-III is sensitive to acquired brain injury, there is nothing exclusive to acquired brain injury or no such thing a specific neuropsychological profile for WAIS-III, idenfied in this systematic review.

CONCLUSIONS

Answering three main questions of this systematic review, the first finding was that the journals which published more articles on WAIS-III have neuropsychologists for main target. These numbers reflect the acknowledgment of the importance of the Wechsler Intelligence Scales in neuropsychological assessment and the growing hegemony of neuropsychological assessment in the evaluation practices.

It is worth noting that only 8 out of 46 (17%) of what we called "technical manual" papers focused on non-English speaking samples. We believe this percentage is very low, considering the worldwide importance of the WAIS.

From the total pool of articles the two most popular neurological samples were selected to analyze how these samples were recruited. There were 19 articles focused on TBI samples and 20 on mixed neuropsychiatric samples. Most of these studies had big samples (sample size varied from 24 up to 400). Around two thirds of the 19 TBI articles describe the participants in detail according to the severity of the injury. But, the so called "mixed neuropsychiatric samples" are most of the times a heterogeneous accumulation of various kinds of diseases. Moreover only 2 out of 20 "mixed clinical" articles in this

review selected the participants according to the injury localization (Tranel et al., 2008; Ryan et al, 2009).

Finally, from the pool of 88 "sample" papers, all studies that used the whole battery and neurologic and/or psychiatric samples (n=29) were selected. The results of these studies lead to the conclusion that although the WAIS-III PSI is sensible to TBI and to other clinical groups (e.g., depression), there is nothing specific to brain injury only, in other words an exclusive neuropsychological profile for the WAIS-III was not found in this review.

The important effect of brain injury localization in the performance of multiples cognitive tests is widely recognized among neuropsychologists; however its potential effect on the WAIS-III performance is apparently neglected by the majority of the studies in this review. We believe that most papers fail to find a more specific profile in acquired brain injury samples, because they give primacy to the etiology over brain injury location. Therefore, we would like to suggest that authors should be strongly encouraged to organize their case material, taking in consideration lesion location.

We wouldn't like to finish without pointing out at least two major limitations of this study. We believe our biggest limitation is that we only used one database: EBSCO Host. We preferred it over PubMed, because we thought we would find a more general overview in psychological research. Although EBSCO Host includes many American Psychological Association (APA) databases, the PubMed could have been a better research tool, when clinical aspects are concerned. A second limitation is that we only read the papers "*full text pdf*" and sometimes other important research is not in open access. Albeit the open access papers from this database can give us a restricted access to the important WAIS-III research, this review introduced us to a new reality: WAIS-III is becoming more and more a neuropsychological instrument, and progressively less a counseling/vocational instrument, but there is still work to be done in what concerns the effect of different brain injury locations on the WAIS-III performance.

STUDY 2: PRIMARY BRAIN TUMOR

Gonçalves, M.A., Simões, M.R., & Castro-Caldas, A. (Published online 04 Mar 2016). Interpreting WAIS-III performance after primary brain tumor surgery. *Applied Neuropsychology*. doi:10.1080/23279095.2015.1084508

TITLE:

Interpreting WAIS-III performance after primary brain tumor surgery

ABSTRACT

The literature lacks information on brain tumor patients' performance on the Wechsler Intelligence Scales (WIS). This study aims to explore the Wechsler Adult Intelligence Scale 3rd Edition performance profile of 23 consecutive brain tumor subjects and 23 matched controls selected from the Portuguese WAIS-III standardization sample, using the technical manual steps recommended for score interpretation. The control group was demographically matched to the tumor group regarding gender, age, education, profession, and geographic region. The technical manual steps recommended for score interpretation were applied. Brain tumor subjects had significantly lower performances on the PIQ, FSIQ, POI, WMI, PSI, Arithmetic, Object Assembly, and Picture Arrangement, though all scaled scores were within the normal range according to the manual tables. Only Vocabulary and Comprehension scatter scores were statistically different between groups. No strengths or weaknesses were found for either group. The mean discrepancy scores do not appear to have clinical value for this population. In conclusion, the study results did not reveal a specific profile for brain tumor patients in the WAIS-III.

KEYWORDS: WAIS-III, brain tumor, intelligence, profile scores, review

INTRODUCTION

Little is known about brain tumor patients' performance in various versions of the Wechsler Intelligence Scales. Neither the American Wechsler Adult Intelligence Scale third edition (WAIS-III) technical manual (Psychological Corporation, 1997), nor the Portuguese WAIS-III technical manual (Wechsler, 2008) include a validation study with brain tumor patients. The most comprehensive reviews on WAIS-III (Kaufman & Lichtenberger, 1999; Tulsky et al, 2003) do not mention any specific information about this clinical group. The same happens with the American version of the WAIS-IV (Holdnack, Dorzdick, Weiss, & Iverson, 2013; Lichtenberger & Kaufman, 2013; Psychological Corporation, 2008).

On January 2014, Gonçalves, Castro-Caldas and Simões (2014) ran a systematic review with the keyword "WAIS-III" in the EBSCOHost database and only two limiters: "full text" and "scholarly (peer reviewed) journals". Two hundred and twenty six papers were identified. Out of these, only one paper (Arreguin-Gonzalez et al., 2011) studied a whole sample with 11 untreated cerebellar tumor patients. There were seven papers with mixed samples of patients with brain tumors among patients with other etiologies. None of them studied brain tumor patients in non-mixed etiology sample. The majority of the seven papers identified in this first search as having brain tumor patients in their samples included less than 5% of patients with this etiology. Pilgrim, Meyers, Bayless and Whetstone (1999) included two tumor patients in a sample of 111 participants (2%). Bossman, Visser-Meily, Post, Lindeman and Van Heugten (2012) included two tumor patients in a sample of 92 participants (2.2%). Ryan, Tree, Norris and Gontkosvsky (2006) included five tumor patients in a sample of 174 participants (2.9%). Karzmark (2009) included four tumor patients in a sample of 118 participants (3.4%). Ryan, Bartels, Morris, Cluff and Gontokovsky (2009) included two tumor patients in a sample of 36 participants (5.6%). Dugbartey et al. (1999, study 2) included one tumor patient in a sample of 14 participants (7.1%). Finally, Tranel, Manzel and Anderson (2008) included 23 post surgery tumor patients in a sample of 160 participants (14.4%).

On January 26th 2015, we searched again for papers on WAIS and brain tumors, in two different databases (EBSCO-Host and PubMed) and the same limiters were applied. We searched six combinations of keywords: (1) "WAIS" and "brain tumor", (2) "WAIS" and "brain neoplasm", (3) "WAIS" and "brain cancer", (4) "Wechsler Adult Intelligence Scale" and "brain tumor", (5) "Wechsler Adult Intelligence Scale" and "brain neoplasm", and (6) "Wechsler Adult Intelligence Scale" and "brain cancer". From the final pool of 42

results, 21 papers focused on WAIS, 11 on WAIS-R, five papers focused on WAIS-III (Arreguin-Gonzalez et al., 2011; Motomura et al., 2014; Quik et al., 2012; Ramirez, Blonsky, Berlin, Carpentier & Talia, 2013; Ryan et al., 2009), and five on WISC, WISC-R, WISC-III or WISC-IV along with WAIS, WAIS-R or WAIS-IV. It is worth noting that these last five papers that used Wechsler Intelligence Scales for the childhood or adolescence ages were all focused on long-term survivors and/or long-term effects of irradiation (e.g., Calonge, 2009; Reimers et al., 2003; Watanable et al., 2011). Among the five papers identified with WAIS-III, two were already identified in the first search (Arreguin-Gonzalez et al., 2011; Ryan et al., 2009), one was a case report (Motomura et al., 2014) and the remaining two didn't use the whole battery (Quik et al., 2012; Ramirez et al., 2013).

Taking into account both searches, brain tumor patients' performance on adult intelligence scales were studied exclusively in the original version of WAIS (e.g., Gregor et al., 1996; Shen et al., 2013; Whelan & Walker, 1988). This issue has not been investigated in the most recent WAIS versions (i.e., WAIS-III and WAIS-IV).

The main goal of our study was to search for a neuropsychological profile of brain tumor patients in the Portuguese adaptation of the WAIS-III. We selected our sample prospectively, during a period of six months, at the most important state oncology hospital in the capital of Portugal, Lisbon.

METHOD

Participants

Following institutional review board approval, participants were selected from a 6 months prospective series of consecutive inpatient and outpatient referrals to the neurology service of the public oncology hospital *Instituto Português de Oncologia Francisco Gentil (IPOFG)*, in Lisbon, Portugal, according to the following criteria: (1) diagnosis of brain tumor, (2) first time in this hospital, (3) absence of prior neurological or psychiatric history, and (4) absence of prior treatment different from neurosurgery (i.e., no chemo- nor radiotherapy). It is worth noting that these cases represent relatively fresh diagnosed patients that had moved through an organized system care, from post-surgery to chemo/radiotherapy/other treatment.

A total of 76 individuals were referred to this Hospital between October 12nd 2011 and April 12nd 2012, but 39 individuals were excluded immediately after the first medical

consultation because they didn't meet the inclusion criteria or they did not accept to collaborate. Fourteen individuals were lost or non-cooperative after the scheduling for the neuropsychological assessment. All participants provided their written informed consent according to the Declaration of Helsinki. Demographics and the motives of exclusion or loss are shown in Table 1.

TABLE 1

Demographic information and reason for exclusion or loss

	Excluded (N=39)			Lost (N=14)			Final sample (N=23)		
	M	(*SD*)	Range	*M*	(*SD*)	Range	*M*	(*SD*)	Range
Age	54.0	(18.77)	10-82	74.0	(13.99)	25-78	54.1	(16.94)	24-77
Admission (days) [a]	27.3	(35.09)	2-189	19,6	(21.27)	8-92	21,8	(20.67)	6-92
Karnofsky Index	68.0	(23.00)	30-100	73.0	(14.51)	50-90	88.0	(15.04)	50-100
	%	*n*		%	*n*		%	*n*	
Gender (% Male)	64.1%	25		21.4%	3		69.6%	16	
Glioblastoma	46.2%	18		85.7%	12		47.8%	11	
EXCLUSION									
No tumor	10.3%	4							
Infratentorial	5.1%	2							
Non-cooperative	2.6%	1		14.4%	2				
Un-testable	15.4%	6		7.1%	1				
Premorbids [b]	17.9%	7		7.1%	1				
Therapy started [c]	12.8%	5		14.4%	2				
Unable to come [d]	12.8%	5		35.7%	5				
No explanation	23.1%	9		21.4%	3				

Note. [a] time elapsed from surgery to admission into this hospital, [b] neurological or psychiatric history, [c] chemo- or radio-therapy, and [d] bedridden out of this hospital and/or with no transportation.

Brain tumor group (N = 23): The final sample included twenty-three patients with a single brain tumor and no history of other neurological or psychiatric diseases. All patients were assessed after brain surgery and before chemo- and/or radiotherapy. Sixteen patients were male and 7 female. Their mean age was 54.09 years (SD = 16.94; range = 24-77) and their mean years of education was 9.83 (SD = 5.56 and range = 4-17).

All patients had neuropathologically confirmed brain tumor. The etiologies of the brain tumors were: glioblastoma (n = 11), astrocytoma (n = 5), oligodendroglioma (n = 2), lymphoma (n = 2), oligoastrocytoma (n = 1), meningeoma (n = 1) and glioma (n = 1). The tumor was lateralized in the right hemisphere in 10 cases, left hemisphere in 10 cases and had a median location in three cases. The location was mostly frontal (n = 9), temporal (n = 5), posterior (occipital, parietal, occipito-parietal and occipito-parieto-temporal, n = 5), median (corpus callosum or thalamus, n = 3) and fronto-temporal (n = 1). The neuropsychological assessment identified: no impairment (n = 4), executive dysfunction (n = 8), aphasia (n = 3), visual-perceptual impairment (n = 2), anterograde amnesia (n = 1), multi-impairment or dementia (n = 4) and pseudo-dementia (n = 1).

Normal control group (N = 23): After the selection of the clinical sample, the control group was obtained from the WAIS-III Portuguese standardization sample. These participants were matched to the selected clinical sample in gender (16 men and 7 women), age (M = 54.04, SD = 17.24 and range = 24-79), education (M = 8.83, SD = 4.58 and range = 4-14), professional status (including functional demands), and region of residence (as shown in Table 2). The matched control sample had no history of either psychiatric or neurological diagnosis.

Table 2
Demographic information for brain tumor patients and matched controls

	Brain tumor (N=23)			Matched controls (N=23)			
	M	(*SD*)	Range	*M*	(*SD*)	Range	*p*
Age	54.09	(16.94)	24-77	54.04	(17.24)	24-79	.993
Education	9.83	(5.56)	4-17	8.83	(4.58)	4-14	.509
Days after surgery	38.00	(22.30)	10-108				

Procedures

After medical consultation, patients were invited to participate in the study. The research protocol consisted of two assessment sessions. In the first session, participants were interviewed and performed a series of cognitive tests besides WAIS-III. The second session consisted of the WAIS-III administration and occurred within two weeks from the first session. All patients were assessed after neurosurgery, but before chemo- and/or radio-therapy, by a trained neuropsychologist. Assessments were scheduled to minimize interference with other medical services and to accommodate patients' tolerance. The first assessment occurred between 10 to 108 days after neurosurgery (*M* = 38; SD = 22.3). All tests were administered in a clinical setting according to the manner prescribed by the test publishers. At the end, all participants received a written report of their scores and other evaluation data.

Information about medical, educational and occupational history, drug and alcohol use, psychiatric and psychological state was obtained from participants and/or family members. Relevant injury-related information was extracted from medical files, including etiology, localization of the injury, and Karnofsky Index. The Karnofsky Performance Status Index, usually called the Karnofsky Index (KI) is a scale that varies every 10% from zero (dead) to 100% (normal, no complaints). This scale is used to rate the general well-

being and activities of daily life. Scores above 50% are attributed to patients who are not bedridden and who are able to function autonomously or with minor help.

Statistical Analyses

The brain tumor subjects and matched control groups were first compared on demographic variables using t-test and Mann-Whitney test.

We followed the steps of score interpretation suggested in the manual (Psychological Corporation, 1997; Wechsler, 2008), Kaufman and Lichtenberger (1999) and Tulsky et al. (2003): (1) the three IQ and the four Index scores analysis (i.e., Verbal IQ or VIQ, Performance IQ or PIQ, Full Scale IQ or FSIQ, Verbal Comprehension Index or VCI; Perceptual Organization Index or POI, Working Memory Index or WMI, and Processing Speed Index or PSI), (2) each subtest alone and subtests by index analysis, (3) scatter analysis to identify the strengths and weaknesses, and (4) WAIS-III composite scores discrepancy analysis.

Mann-Whitney test was used to compare groups; and the Cohen's *r* was used to calculate the effect size. For each family of tests (i.e., IQ scores, Indexes scores and subtest scores), we corrected for multiple comparisons using the Bonferroni Test.

RESULTS

Characteristics of the sample

As shown in table 1, the excluded and lost participants had less functionality, this fact is suggested by a higher Karnosfky Index. As shown in Table 2, independent-samples t-tests indicated that there were no differences between the two groups in terms of age and education; $t(44) = -0.01$, $p = .993$, and $t(44) = -0.67$, $p = .509$, respectively. Subjects from both groups were matched for gender (16 men and 7 women), professional status, and geographic region where the subject lives.

IQ, Index and Digit Span scores

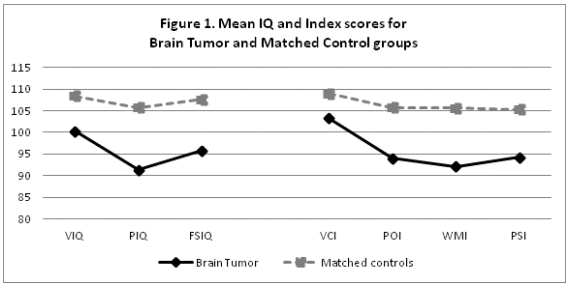
Group comparisons for WAIS-III IQ, Index and subtest scaled scores for brain tumor patients and matched control groups are reported in table 3. Score profiles are also shown in figures 1 and 2.

Mann-Whitney Tests indicated VIQ and VCI scores did not differ significantly for tumor and matched control groups, $Z = -1.58$, $p = .113$, and $Z = -1.10$, $p = .271$,

respectively. However the brain tumor group had significant lower PIQ, FSIQ, POI, WMI and PSI scores than the matched control group, Z = -2.64, p = .008, Z = -2.43, p = .015, Z = -2.06, p = .040, Z = -2.76, p = .006, and Z = -2.16, p = .030, respectively. Furthermore, Cohen's effect size value suggested a moderate to large practical significance for the lower performance of the brain tumor group than the matched controls for the PIQ, FSIQ, POI, WMI and PSI scores, r = .39, r = .36, r = .30, r = .41, and r = .32, respectively.

Differences in the scaled scores were not found for the two groups on nine out of the fourteen subtests namely on five verbal and on four performance subtests: Vocabulary, Similarities, Information, Comprehension, and Letter Number Sequencing; Z = -.243, p = .808, Z = -.818, p = .413, Z = -1.849, p = .064, Z = -.066, p = .947, and Z = -1.864, p = .062, respectively, and again for Picture Completion, Block Design, Matrix Reasoning, and Symbol Search; Z = -1.943, p = .052, Z = -1.670, p = .095, Z = -1.451, p = .147, and Z = -1.620, p = .105, respectively. However, group differences with a low practical significance were found on Object Assembly, Arithmetic, and Picture Arrangement subtests, Z = -2.99, p = .003, r =.44, Z = -2.94, p = .003, r = .43, Z = -2.69, p = .007, r = .43, Z = -2.46, p = .014, r = .36, Z = -2.45, p = .014, r = .36, respectively. Finally, differences with a moderate practical significance were found for Digit Symbol and Digit Span, Z = -2.45, p = .014, r = .36, and Z = -2.455, p = .014, r = .36, respectively.

With Bonferroni correction, the groups remained statistically different for PIQ, FSIQ, WMI, Arithmetic and Object Assembly.



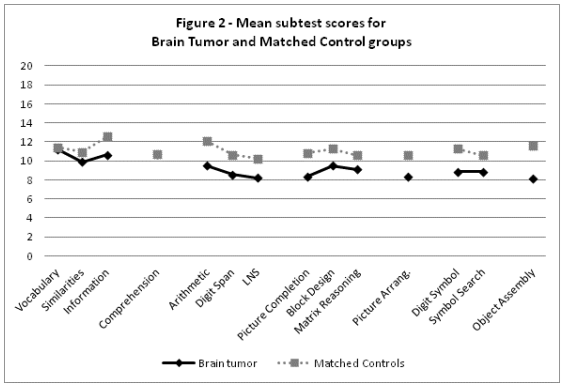


Table 3 WAIS-III scaled scores for brain tumor and matched controls

	Brain tumor (N=23)			Matched controls (N=23)				Cohen's
	M	(*SD*)	Range	*M*	(*SD*)	Range	*p*	*r*
IQ Scores								
VIQ	100.26	(15.40)	67-125	108.39	(13.25)	88-136	.113	
PIQ	91.35	(16.93)	65-121	105.75	(18.33)	68-141	.008*	.39
FSIQ	95.78	(17.17)	67-126	107.65	(15.86)	76-136	.015*	.36
Indexes								
VCI	103.26	(16.75)	70-134	109.00	(13.44)	91-134	.271	
POI	94.00	(15.73)	68-123	105.75	(17.90)	69-137	.040	.30
WMI	92.13	(13.88)	65-115	105.65	(14.31)	77-132	.006*	.41
PSI	94.22	(18.21)	60-122	105.25	(16.39)	71-130	.030	.32
Subtests								
V	11.22	(2.86)	4-16	11.43	(3.20)	6-16	.808	
S	9.91	(4.38)	3,17	10.91	(2.56)	6-16	.413	
A	9.52	(2.69)	5-15	12.04	(2.92)	5-16	.003*	.43
DS	8.57	(2.69)	5-15	10.65	(2.90)	5-15	.014	.36
I	10.61	(3.09)	4-17	12.57	(2.63)	8-17	.064	.27
C	10.70	(3.53)	4-17	10.74	(2.78)	7-15	.947	
LNS	8.22	(3.03)	3-14	10.26	(3.74)	4-17	.062	.28
PC	8.35	(3.11)	3-14	10.85	(3.59)	5-17	.052	.29
CD	8.83	(3.73)	2-15	11.25	(3.52)	4-7	.014	.36
BD	9.52	(2.79)	3-14	11.25	(3.23)	5-18	.095	.25
MR	9.09	(2.97)	4-14	10.60	(2.93)	5-16	.147	
PA	8.30	(2.53)	4-13	10.60	(2.60)	6-17	.007	.40
SS	8.83	(3.41)	2-14	10.60	(3.12)	4-16	.105	
OA	8.17	(3.33)	2-17	11.55	(2.96)	7-18	.003*	.44

Notes. FSIQ = Full Scale Intelligence IQ, VIQ = Verbal IQ, PIQ = Performance IQ, VCI= Verbal Comprehension Index, POI = Perceptual Organization Index, WMI = Working Memory Index, PSI = Processing Speed Index, V = Vocabulary, S = Similarities, A = Arithmetic, DS = Digit Span, I = Information, C = Comprehension, LNS = Letter Number Sequencing, PC = Picture Completion, CD = Digit Symbol – Coding, BD = Block Design, MR = Matrix Reasoning, PA = Picture Arrangement, SS = Symbol Search, and OA = Object Assembly.

* *p* values that remained significant after Bonferroni correction for multiple comparisons.

Strengths and weaknesses (scatter analysis)

In the scatter analysis, the participant is compared to his own mean performance. Scatter scores were calculated according to scoring instructions in the WAIS-III manual: at first, the sum of the verbal scaled scores was divided by the number of verbal subtests administered (n = 7) to determine the mean verbal score. The same procedure was done to calculate the mean performance score. Then, the scatter score for each test was calculated by subtracting the mean verbal/performance score from the subtest scaled score.

Mean scatter scores for brain tumor patients and matched control groups are reported in table 4. Only Vocabulary and Comprehension were significantly different between groups, $Z = -1.99$, $p = .047$, $r = .29$, and $Z = -2.46$, $p = .014$, $r = .36$, respectively. Scores did not differ significantly between groups for any other subtest, namely: Similarities, Arithmetic, Digit Span, Information, Letter Number Sequencing, Picture

Completion, Digit Symbol, Block Design, Matrix Reasoning, Picture Arrangement, Symbol Search, and Object Assembly, $Z \geq -1.43$, $p \geq .153$.

Table 4

Scatter scores (i.e., mean differences between subtests' scaled scores and mean verbal/performance score) for brain tumor patients and matched controls

	Brain tumor (N=23)			Matched controls (N=23)				Cohen's
	M	(*SD*)	Range	*M*	(*SD*)	Range	*p*	*r*
Vocabulary	1.22	(1.52)	-2.43-4.57	0.21	(1.63)	-3.14-3.14	.047	.29
Similarities	0.30	(2.55)	-4.29-6.29	-0.36	(1.91)	-4.14-3.29	.339	
Arithmetic	-0.17	(2.20)	-4.71-3.71	0.81	(2.83)	-5.29-6.43	.253	
Digit Span	-0.12	(2.50)	-4.86-3.43	-0.53	(1.17)	-3.57-2.43	.262	
Information	0.79	(1.59)	-3.57-3.86	1.33	(0.91)	0.14-3.29	.169	
Comprehension	1.03	(2.05)	-2.57-4.86	-0.41	(1.43)	-3.57-1.86	.014	.36
LNS	-1.57	(1.94)	-5.14-1.86	-0.93	(2.24)	-5.86-3.00	.429	
Picture Completion	-0.32	(1.73)	-2.86-3.14	-0.27	(2.30)	-3.86-4.71	.912	
Digit Symbol	0.17	(1.65)	-2.86-2.43	0.44	(1.72)	-3.00-3.86	.307	
Block Design	0.79	(1.77)	-1.86-5.57	0.66	(1.52)	-2.29-3.00	.153	
Matrix Reasoning	0.36	(1.60)	-2.86-3.57	-0.26	(1.63)	-3.00-2.00	.180	
Picture Arrangement	-0.42	(1.68)	-3.43-3.29	-0.49	(1.53)	-3.71-2.29	.794	
Symbol Search	0.10	(1.68)	-3.43-3.71	-0.31	(2.25)	-6.29-3.29	.869	
Object Assembly	-0.50	(2.15)	-5.14-3.29	0.41	(2.12)	-2.43-6.14	.792	

Later, we compared these mean scatter scores to table B.3.2 in Appendix B from the technical manual. When the absolute value of the difference was equal to or greater than the reference value in the table (95% level of confidence), the difference was classified as strength (for positive values) or weakness (for negative values). Brain tumor and matched control groups' mean scatter scores fell within the normal range according the norms' tables (i.e., no strengths or weaknesses were identified).

Discrepancy comparisons (composite measures)

Mean discrepancy comparisons for brain tumor patients and matched control groups are reported in table 5. Scores did not differ significantly between groups for any discrepancy ($p > .05$).

Table 5
WAIS-III discrepancy scores for brain tumor patients and matched controls

	Brain tumor (N=23)			Matched controls (N=23)			
	M	(*SD*)	Range	*M*	(*SD*)	Range	*p*
VIQ – PIQ	9.35	(9.93)	-19-24	3.14	(12.37)	-24-23	.860
VCI – POI	9.00	(11.49)	-24-29	4.30	(12.63)	-19-27	.150
CVI – WMI	10.61	(15.03)	-23-40	3.87	(9.58)	-22-22	.097
POI – PSI	0.65	(10.24)	-20-17	-0.67	(14.35)	-24-32	.647
VCI – PSI	9.22	(12.63)	-13-43	2.95	(11.13)	-22-20	.162
POI – WMI	3.57	(11.83)	-24-18	0.22	(11.88)	-19-32	.141
WMI – PSI	-1.39	(13.04)	-22-33	-1.05	(10.44)	-24-31	.760

Note. VIQ = Verbal IQ, PIQ = Performance IQ, VCI= Verbal Comprehension Index, POI = Perceptual Organization Index, WMI = Working Memory Index, PSI = Processing Speed Index, and LNS = Letter Number Sequencing

The mean discrepancy scores of each goup were compared to the norms' Supplementary Tables B.1 (95% level of confidence). The brain tumor group's mean discrepancy scores were different from the reference scores on the VIQ-PIQ (though the observed discrepancy score of 9.35 can be found in 38.1% of the standardization sample), VCI-POI (though the observed discrepancy score of 9.00 can be found in 43.5% of the standardization sample) and the VCI-WMI discrepancy (though the observed discrepancy score of 10.61 can be found in 38.6% of the standardization sample).

DISCUSSION

Brain tumor patients performed at a lower level than the matched control subjects on the PIQ, the FSIQ and the WMI. However all mean IQ and Index scores ranged between 100 ± 15. Therefore all mean IQ and Indexes scores should be considered "normal" according to the technical manual.

After Bonferroni correction, three out of fourteen WAIS-III subtests were statistically different between the brain tumor patients and the matched control subjects. Despite their lower performance in comparison to the control group, brain tumor patients' scaled scores were all within the normal range.

Additionally, brain tumor patients had larger mean scatter scores on Vocabulary and Comprehension when compared to the matched controls, but the mean scaled scores on Vocabulary and Comprehension subtests were not significantly different between groups. These findings (a) suggest that these two subtests might be more preserved than other subtests among brain tumor patients, and (b) support the use of the Vocabulary subtest as a premorbid intelligence measure (Alves, Simões, & Martins, 2012). However, all mean scatter scores of the brain tumor group were within the normal range according to

the technical manual. Therefore, no significant strength or weakness was identified for the brain tumor patients.

Finally, when comparing mean discrepancy scores, no significant group differences were found. Three discrepancies were higher than expected (i.e., VQI-PIQ, VCI-POI and VCI-WMI), but similar scores to our tumor group are common in more than one third of the Portuguese standardization sample.

Overall, there is no WAIS-III profile or a special score that could obviously point to cognitive impairment in this brain tumor group, but there were significant differences between groups in the WAIS-III performance.

A possible explanation for the absence of a specific profile is the use of means scores in this study, which may have masked the heterogeneity of cognitive impairment associated with the diversity of brain injury locations. Future studies on the topic ought to take into account brain tumor location in the inclusion criteria, as it was done in earlier versions of the WAIS (e.g., Whelan, & Walker, 1988), knowing that only lateralizing brain lesion on the right *versus* left hemisphere is sometimes misleading (e.g., Mattis, & Hannay, 1992; Ryan et al., 2009). Some of these tumors may have had a slow progressive growth, that left space for the brain to readjust; and once size effect was removed through surgery, the cognitive functions may have returned to the premorbid levels.

Even though patients were selected in a consecutive manner, the small sample size is an important limitation. We tried to deal with this limitation by investigating the effect size. To guarantee that patients had no other treatment aside from surgery (i.e., no chemo- nor radiotherapy), the assessment had to be performed in the acute and post-acute stages. Being this a limitation, because patients in the acute stage are not as cognitively stable as in the chronic stage.

In short, the results of this study suggest that WAIS-III is sensitive to brain tumor, but there is no profile or score that could be used as an alert sign. Cognitive impairment due to primary brain tumor can go unnoticed even to an experienced neuropsychologist that will only follow the WAIS-III manual recommendations for score interpretation. Studies focused on brain injury location are necessary to unravel how different brain injury locations and/or different cognitive impairments affect WAIS-III performance.

STUDY 3: MIXED NEUROLOGICAL SAMPLE

Gonçalves, M.A., Moura, O., Castro-Caldas, A., Simões, M.R. (published online 06 Jul 2016). Searching for a brain injury’ s WAIS-III profile. *Applied Neuropsychology*. doi: 10.1080/23279095.2016.1199429

TITLE:

Searching for a neurologic injury's WAIS-III profile

ABSTRACT:

OBJECTIVE: This study is aimed to investigate the presence of a WAIS-III cognitive profile in a Portuguese neurologic injured sample. METHOD: The Portuguese WAIS-III was administered to 81 mixed neurologic patients and 81 healthy matched controls selected from the Portuguese standardization sample. RESULTS: Although the mixed neurologic injury group performed significantly lower than the healthy controls for the majority of the WAIS-III scores (i.e., composite measures, discrepancies, and subtests), the mean scores were within the normal range, and therefore at risk of being unobserved in a clinical evaluation. ROC curves analysis showed poor to acceptable diagnostic accuracy for the WAIS-III composite measures and subtests (Working Memory Index and Digit Span revealed the highest accuracy for discriminating between participants, respectively). Multiple regression analysis showed that both literacy and the presence of brain injury were significant predictors for all of the composite measures. In addition, multiple regression analysis also showed that literacy, age of injury onset and years of survival predicted all seven composite measures for the mixed neurologic injured group. CONCLUSIONS: Despite the failure to find a WAIS-III cognitive profile for mixed neurologic patients, the results showed a significant influence of brain lesion and literacy in the performance of the WAIS-III.

KEYWORDS: Wechsler Adult Intelligence Scale, 3rd Edition; intelligence; mixed neurologic injury; diagnostic accuracy; literacy.

INTRODUCTION

The Wechsler Adult Intelligence Scale's (WAIS) predecessor was constructed in 1939, and its name was Wechsler-Bellevue (W-B) Scale (Wechsler, 1944). Sixteen years of clinical work evolved and, after some procedure changes and new norm tables, the W-B became the original WAIS (Wechsler, 1955). Another twenty six years passed and the WAIS' norms were updated with minor item changes, turning the WAIS into the WAIS-R (Wechsler, 1981). After David Wechsler´s death, the WAIS underwent two large revisions and subsequent standardizations, specifically the creation of WAIS-III (The Psychological Corporation, 1997) and WAIS-IV (The Psychological Corporation, 2008). Beyond the key of updating norms, Kaufman and Lichtenberger (1999, 2013) pointed out several overt and covert neuropsychological goals that prompted and guided the revision of both WAIS-III and WAIS-IV. Gonçalves, Simões and Castro-Caldas (2014b, 2015) reviewed 226 papers on WAIS-III and corroborated the idea that the WAIS was eager to be more and more a neuropsychological affair.

WAIS, WAIS-R and WAIS-III are "the single most widely used instrument for measuring intelligence today. Despite its construction as a test of cognitive aptitude, the WAIS is ubiquitous in neuropsychological batteries that assess impairments (…). It has excellent psychometric properties, very high test-retest reliability in both healthy (…) and clinical populations (…), and an enormous database to provide comparison and standardization." (Gläscher et al., 2009, p.681). According to The Psychological Corporation (2008), Kaufman and Lichtenberger (1999), Tulsky et al. (2003), and Gonçalves, Simões and Castro-Caldas (2015) most of the WAIS-III validation and/or clinical research are conducted in the context of neuropsychological studies, and its most relevant work is done with Traumatic Brain Injury (TBI), temporal lobe Epilepsy, aging neurodegenerative diseases (such as, Alzheimer's, Huntington's, and Parkinson's Diseases), Mild Cognitive Impairment (MCI), Multiple Sclerosis, Korsakoff's Syndrome, and samples with mixed neuropsychiatric diseases. On the other hand, as reported by The Psychological Corporation (2008) and Kaufman and Lichtenberger (2013), the WAIS-IV validation studies focused on neurodevelopmental disorders (i.e., Intellectual Disability, Specific Learning Disorders, Attention Deficit Hiperactivity Disorder, among others), but they also report studies on psychiatric (i.e., Major Depressive Disorder) and neurological (i.e., TBI, MCI and Mild Probable Alzheimer's Dementia) disorders.

From the psychometric point of view, Flynn (2009) favored WAIS-IV over WAIS-III. However, the clinical perspective of Loring and Bauer (2010), favored WAIS-III over

WAIS-IV. Because there are no WAIS-IV norms for the Portuguese speaking population, our study used WAIS-III.

A large number of WAIS-III studies have observed that individuals with TBI performed lower than 85 on the Processing Speed Index (PSI) (e.g., The Psychological Corporation, 1997; Hawkins, 1998; Fisher, Ledbetter, Cohen, Marmor, & Tulsky, 2000; Axelrod, Fichtenberg, Liethen, Czarnota, & Stucy, 2001; Kennedy, Clement, & Curtis, 2003), but the low score on PSI is also observed in the Huntington Disease (The Psychological Corporation, 1997; Hawkins, 1998) and Schizophrenia (The Psychological Corporation, 1997; Hawkins, 1998). A low PSI score is the most consistent cognitive impairment profile among the studies that used at least 11 of the 14 subtest of the WAIS-III.

There are also numerous studies that used only some subtests from the whole battery, and a few that used all subtests from a specific WAIS-III Index like Working Memory Index (WMI) (e.g., Earnst et al., 2001; Noé, Ferri, Colomer, Moliner, & Chirivella, 2010) or WMI + PSI (Bowler et al., 2001; Kennedy, Clement, & Curtis, 2003) to assess frontal lobe dysfunctions.

Therefore, the present study was aimed to investigate the presence of a WAIS-III cognitive profile in Portuguese brain lesioned patients with mixed neurologic diseases. Specifically, (1) this study analyzed the presence of cognitive strengths and weaknesses in individuals with mixed neurologic injury, (2) the diagnostic accuracy of the WAIS-III to correctly discriminate between mixed neurologic injured patients and healthy matched controls, and (3) the predictive effect of mixed neurologic injury (e.g., lesion onset, years of evolution, etc.) on the WAIS-III composite measures.

METHOD

Participants

The participants were 81 healthy controls and 81 brain lesioned patients with mixed neurologic diseases matched for gender (37 female and 44 male), age, literacy (completed years of formal education), professional status and geographic region. Table 1 shows the descriptive statistics for age, literacy, age at disease onset and years of disease duration. The mixed neurologic injured group included 23 patients with primary brain tumor (for more detailed information see Gonçalves, Simões & Castro-Caldas, 2016), 30 patients with refractory epilepsy (for more detailed information see Gonçalves, Simões & Castro-Caldas, submitted), 20 patients submitted to brain surgery after subarachnoid hemorrhage (SAH),

four TBI patients and four stroke patients with aphasia. All brain tumor and refractory epileptic patients were recruited consecutively in prospective series, but the SAH patients were mainly selected retrospectively from a long term follow-up study. Prior and/or actual neurologic or psychiatric history was considered as an exclusion criteria for both clinical (except for the refractory epileptic patients) and control groups.

In the mixed neurologic group, 73 out of the 81 participants already had or were assigned to have brain surgery. The brain injury was lateralized in the left hemisphere in 31 cases, in the right hemisphere in 34 cases, bilaterally in 8 cases, and finally in the medial regions (e.g., corpus callosum or thalamus) in 4 cases. The mixed neurologic injury group had 76 right-handed and 2 left-handed subjects.

Table 1 – Demographic information about healthy controls and mixed neurologic injured patients

	Healthy controls (N=81)			Mixed neurologic injured (N=81)				
	Mean	SD	Range	Mean	SD	Range	*t* (160)	*p-value*
Age	49.05	16,03	22-82	49.68	16,01	21-80	-0.250	.803
Literacy	8.90	4.03	0-14	9.23	4,60	0-17	-0.490	.625
Age onset				36.96	21.97	0-77		
Duration (years)				12.59	14.03	0.03-63		

Measures and Procedures

All participants were assessed after institutional review board approval and informed consent. The research protocol consisted of two psychological assessment sessions. After informed consent, in the first session, participants were interviewed and then performed a battery of cognitive tests. The second session consisted of the Portuguese WAIS-III (Wechsler, 2008) administration and occurred within two weeks from the first session. All tests were administered in a clinical setting according to the manner prescribed by the test publishers. Only psychologists with extensive experience in neuropsychological evaluation administered, scored and interpreted the results. All participants received a written report of their scores and other evaluation data.

Statistical Analysis

Statistics were computed in SPSS Statistics 22 and MedCalc version 12.7. The patients with mixed neurologic injury and matched control groups were compared on WAIS-III composite measures (i.e., IQ and Indexes), composite measures' discrepancies, subtests' scaled scores and subtests scatter scores using *t-test*. ROC curves were performed to evaluate the contribution of each variable to accurately discriminate between mixed neurologic injured patients and healthy controls [area under the curve (AUC) values] and to identify the optimal cut-off score (Youden index *J*). The more accurately a task discriminates between groups, the higher is its AUC value. An AUC of .5 to .7 indicates poor discrimination, .7 to .8 indicates acceptable discrimination, .8 to .9 is excellent discrimination, and .9 to 1.0 indicates outstanding discrimination (Hosmer, Lemeshow, & Sturdivant, 2013). Multiple regression analysis was used to investigate the predictive effect of mixed neurologic injury (e.g., lesion onset, years of evolution, etc.) on the WAIS-III composite measures.

RESULTS

Composite Measures and Discrepancies: Group Differences

As showed in Table 2, mixed neurologic injured patients had significant lower composite measures (i.e., VIQ, PIQ, FSIQ, CVI, POI, WMI and PSI) than healthy controls, $t(154) > 3.816$, $p \geq .001$. Mixed neurologic injured patients had also significant lower scores for VIQ – PIQ and CVI – WMI discrepancies, $t(158) = -2.252$, $p = .026$ and $t(150) = -3.390$, $p = .001$ respectively. However mean scores for all composite measures and all discrepancies were within the average range of norms tables for both groups, this means that despite the statistical differences, all scores should be interpreted as normal scores.

Table 2 – WAIS-III composite measures and discrepancies for mixed neurologic injured patients and healthy controls

	Healthy controls (N=81)			Mixed neurologic injured (N=81)					
	Mean	SD	Range	Mean	SD	Range	*t*	*df*	*p*
IQ Scores									
FSIQ	105.99	16.03	66-137	93.65	17.59	58-141	4.647	159	<.001
VIQ	105.96	14.15	68-160	96.79	15.65	67-133	3.913	160	<.001
PIQ	105.04	16.90	68-141	91.54	18.88	53-148	4.766	158	<.001
Indexes									
VCI	107.79	14.02	67-134	99.83	15.36	70-134	3.446	160	.001
POI	104.41	16.71	64-146	93.44	18.41	54-144	3.956	159	<.001
WMI	104.36	14.61	70-142	90.27	16.41	61-126	5.564	149	<.001
PSI	104.73	15.93	66-130	94.27	18.26	57-150	3.816	154	<.001
Discrepancies									
VIQ – PIQ	1.10	11.42	-29-31	0.026	13.60	-23-40	-2.252	158	.026
VCI – POI	3.75	12.58	-30-34	0.246	15.10	-34-40	-1.165	158	.246
CVI – WMI	3.57	12.33	-22-44	0.001	15.05	-23-77	-3.390	150	.001
POI – PSI	-0.71	14.76	-66-32	0.759	13.04	-21-60	-0.307	155	.759
VCI – PSI	2.78	14.88	-33-50	0.123	17.22	-29-77	-1.552	155	.123
POI – WMI	-0.25	14.83	-36-42	0.053	16.60	-44-60	-1.953	150	.053
WMI – PSI	-0.62	14.27	-41-29	0.110	15.32	-30-42	1.608	148	.110

Notes: VIQ = Verbal IQ, PIQ = Performance IQ, VCI= Verbal Comprehension Index, POI = Perceptual Organization Index, WMI = Working Memory Index, and PSI = Processing Speed Index

Composite Measures: Diagnostic Accuracy

The results from the ROC curve analysis showed that WMI was the most relevant measure for discriminating between mixed neurologic injured and healthy matched controls, with an AUC value of .736 (i.e., a randomly selected patient with TBI will have a lower score than a randomly selected healthy matched controls approximately 73.6% of the time) (see Table 3). The remaining variables showed poor discrimination (AUC = [.5 – .7[).

In addition, the Youden index was calculated (J = sensitivity + specificity - 1) to analyze the optimal cut-off scores for the composite measures and discrepancy scores. The optimal cut-off score of the WMI (≤ 86) revealed the highest Youden index (J = .358), which yielded a sensitivity of 47.1% and a specificity of 88.7%.

Table 3 – ROC curve analysis for the composite measures and discrepancies

	AUC	Optimal cut-off score	Youden index	Sensitivity	Specificity
Composite measures					
FSIQ	.702	≤103	.328	74.4	58.7
VIQ	.667	≤99	.271	60.5	66.7
PIQ	.704	≤104	.325	80.0	52.5
VCI	.654	≤97	.271	48.1	79.0
POI	.675	≤82	.258	33.3	92.5
WMI	.736	≤86	.358	47.1	88.7
PSI	.685	≤90	.303	48.1	82.3
Discrepancies					
VIQ – PIQ	.598	>11	.193	37.0	82.3
VCI – POI	.559	>10	.141	42.0	72.2
CVI – WMI	.644	>14	.256	38.0	87.7
POI – PSI	.514	<-22	.088	0.0	91.1
VCI – PSI	.564	>-2	.161	74.4	41.8
POI – WMI	.598	>2	.237	62.0	61.7
WMI – PSI	.596	≤-7	.177	50.7	67.1

Notes: VIQ = Verbal IQ, PIQ = Performance IQ, VCI= Verbal Comprehension Index, POI = Perceptual Organization Index, WMI = Working Memory Index, and PSI = Processing Speed Index

Composite Measures: Predictive Effect

Multiple regression analysis was used to analyze if gender, literacy and the presence of mixed neurologic injury significantly predicted the scores of the composite measure for all participants (n = 162, first part of Table 4). The results of the regression indicated that the three predictors explained up to one third of the variance ($.149 < R^2 < .369$, $p < .001$). The presence of mixed neurologic injury and literacy were significant predictors for all outcomes.

In addition, multiple regression analysis was also used to analyze if the literacy, age of lesion onset and years of disease presence significantly predict the mixed neurologic injured group' scores of each composite measure (n = 81, second part of Table 4). The results of the regression analysis indicated that literacy, age of onset and years of evolution explained from 22% to 59.9% of the total variance and were significant predictors for all composite measures.

Table 4 – Multiple Regression Analysis for the seven composite measures

Total sample	Predictors	R^2	$F(df)$	p	β	t	p
FSIQ		.299	F (3,157) = 22.338	< .001			
	Gender				.034	0.502	.617
	Literacy				.422	6.311	<.001
	Brain lesion				-.359	-5.376	<.001
VIQ		.300	F (3,158) = 22.587	< .001			
	Gender				.071	1.063	.289
	Literacy				.455	6.833	<.001
	Brain lesion				-.313	-4.702	<.001
PIQ		.245	F (3,156) = 16.855	< .001			
	Gender				-.018	-0.252	.802
	Literacy				.345	4.957	<.001
	Brain lesion				-.365	-5.237	<.001
VCI		.369	F (3,158) = 30.736	< .001			
	Gender				-.001	-.011	.991
	Literacy				.548	8.655	<.001
	Brain lesion				-.284	-4.490	<.001
POI		.179	F (3,157) = 11.409	< .001			
	Gender				.022	.305	.761
	Literacy				.298	4.115	<.001
	Brain lesion				-.309	-4.269	<.001
WMI		.296	F (3,146) = 20.475	< .001			
	Gender				.076	1.095	.275
	Literacy				.345	4.965	<.001
	Brain lesion				-.436	-6.269	<.001
PSI		.211	F (3,152) = 13.538	< .001			
	Gender				-.123	-1.712	.089
	Literacy				.333	4.612	<.001
	Brain lesion				-.301	-4.176	<.001

Mixed neurologic injured	Predictors	R^2	$F(df)$	p	β	t	p
FSIQ		.417	F (3,76) = 18.144	< .001			
	Literacy				.627	6.526	<.001
	Lesion onset				.678	5.375	<.001
	Years of evolution				.439	3.466	.001
VIQ		.478	F (3,76) = 23.166	< .001			
	Literacy				.652	7.161	<.001
	Lesion onset				.674	5.645	<.001
	Years of evolution				.327	2.726	.008
PIQ		.277	F (3,75) = 9.562	< .001			
	Literacy				.512	4.751	<.001
	Lesion onset				.578	4.076	<.001
	Years of evolution				.472	3.316	.001
VCI		.595	F (3,76) = 39.623	< .001			
	Literacy				.798	10.142	<.001
	Lesion onset				.632	6.123	<.001
	Years of evolution				.336	3.245	.002
POI		.220	F (3,76) = 7.166	< .001			
	Literacy				.456	4.103	<.001
	Lesion onset				.518	3.548	.001
	Years of evolution				.423	2.887	.005
WMI		.352	F (3,66) = 11.947	< .001			
	Literacy				.417	3.890	<.001
	Lesion onset				.736	5.148	<.001
	Years of evolution				.381	2.628	.011
PSI		.291	F (3,72) = 9.829	< .001			
	Literacy				.457	4.236	<.001
	Lesion onset				.648	4.614	<.001
	Years of evolution				.573	4.066	<.001

Notes: VIQ = Verbal IQ, PIQ = Performance IQ, VCI= Verbal Comprehension Index, POI = Perceptual Organization Index, WMI = Working Memory Index, and PSI = Processing Speed Index

Subtests: Group Differences

As showed in the Table 5, mixed neurologic injured patients had significant lower scaled scores than the healthy controls for the majority of the subtests, the exceptions were Vocabulary and Comprehension, $t(160) = 0.840$, $p > .402$ and $t(160) > 0.797$, $p = .427$, respectively. Although inferential analysis showed that healthy controls outperformed mixed neurologic injured patients in the WAIS-III subtests, the scaled scores of the mixed neurologic injury group were within norm. Once all scores should be interpreted as normal scores, they are at risk of being unobserved in clinical evaluation.

Table 5 - WAIS-III substest scaled scores for mixed neurologic injured patients and healthy controls

	Healthy controls (N=81)			Mixed neurologic injury (N=81)					
	Mean	SD	Range	Mean	SD	Range	t	df	*p*
Vocabulary	11.12	3.12	3-16	10.73	2.87	4-17	0.840	160	.402
Similarities	10.84	2.71	5-17	9.46	3.45	1-17	2.835	152	.005
Arithmetic	10.77	3.10	4-16	8.49	3.23	1-15	4.566	159	<.001
Digit Span	10.81	2.68	5-19	8.27	3.19	3-17	5.499	160	<.001
Information	11.79	3.11	4-19	9.67	3.38	3-17	4.164	160	<.001
Comprehension	10.68	2.77	4-10	10.30	3.32	3-17	0.797	160	.427
LNS	10.81	3.26	4-17	8.33	2.86	3-14	4.975	151	<.001
Picture Completion	10.81	3.04	4-17	8.27	3.41	1-15	5.009	160	<.001
Digit Symbol Coding	11.01	3.39	4-17	8.59	3.55	2-19	4.436	160	<.001
Block Design	10.64	3.13	4-18	9.31	3.53	2-18	2.543	160	.012
Matrix Reasoning	10.59	3.13	4-19	9.09	3.34	2-19	2.962	160	.004
Picture Arrangement	10.98	3.18	3-17	8.41	2.97	2-16	5.294	159	<.001
Symbol Search	10.82	2.99	3-16	9.11	3.60	2-19	3.235	153	.001

Notes: LNS = Letter Number Sequencing

Subtests: Diagnostic Accuracy

The results from the ROC curve analysis demonstrated that Digit Span was the most relevant subtest for discriminating between mixed neurologic injured patients and healthy controls, with an AUC value of .736 (see Table 6). The remaining subtests showed poor discrimination.

The Youden index (J = sensitivity + specificity - 1) for the WAIS-III subtests was also computed to analyze the optimal cut-off scores. The optimal cut-off score of the Digit Span (≤ 8) revealed the highest Youden index ($J = .370$), yielding a sensitivity of 54.3% and a specificity of 82.7%.

Table 6 – ROC curve analysis for the subtests scaled scores

Subtest	AUC	Optimal cut-off score	Youden index	Sensitivity	Specificity
Vocabulary	.554	≤ 10	.148	46.9	67.9
Similarities	.621	≤ 9	.284	51.9	76.5
Arithmetic	.694	≤ 9	.341	65.0	69.1
Digit Span	.736	≤ 8	.370	54.3	82.7
Information	.680	≤ 10	.296	61.7	67.9
Comprehension	.527	≤ 5	.086	9.9	98.8
Letter Number Sequencing	.715	≤ 9	.340	65.3	68.7
Picture Completion	.708	≤ 10	.308	76.5	54.3
Digit Symbol Coding	.696	≤ 9	.321	60.5	71.6
Block Design	.610	≤ 11	.185	72.8	45.7
Matrix Reasoning	.630	≤ 10	.197	71.6	48.1
Picture Arrangement	.723	≤ 8	.355	54.3	81.2
Symbol Search	.660	≤ 10	.306	73.7	57.0

Subtests: Scatter Analysis

In the scatter analysis each participant is compared to his own mean performance. Scatter scores were calculated according to scoring instructions in the WAIS-III manual. First, the scatter score was calculated by subtracting the mean of the verbal or performance subtests from each subtest scaled score. Scatter scores' results are presented in the first part of Table 7. Second, we compared these scatter scores to Table B.3.2 in Appendix B from the WAIS-III technical manual. When the absolute value of the difference was equal to or greater than the reference value in the table (95% level of confidence), the difference was classified as strength (for positive values) or weakness (for negative values). Strengths and weaknesses were calculated for each participant and their counting is presented in the first part of Table 7.

Once again, for scatter scores presented in the second part of Table 7, there were two of the CVI subtests (i.e., Vocabulary and Comprehension), and two of the WMI subtests (i.e., Digit Span and Letter Number Sequencing) that had significantly different scatter scores, $t(160) = -4.964$, $p < .001$, $t(150) = -4.713$, $p < .001$, $t(148) = 2.861$, $p = .005$ and $t(154) = 3.335$, $p = .001$ respectively. Nevertheless, according to the norm tables these mean differences are not clinically relevant.

Table 7: WAIS-III scatter analysis for mixed neurologic injured patients and healthy controls

	Healthy controls (N=81)			Mixed neurologic injury (N=81)					
	Mean	SD	Range	Mean	SD	Range	t	df	*p*-value
Vocabulary	0.15	1.58	-4.86-3.14	1.35	1.50	-3.00-7.43	-4.964	160	<.001
Similarities	-0.14	1.78	-416-4.14	0.19	2.26	-6.57-6.29	-1.009	160	.315
Arithmetic	-.021	2.43	-6.71-6.43	-0.75	2.22	-8.00-4.33	1.480	160	.141
Digit Span	-0.16	1.67	-3.57-4.14	-1.05	2.24	-6.14-3.71	2.861	148	.005
Information	0.82	1.71	-4.43-6.43	0.34	1.84	-3.57-7.50	1.711	158	.089
Comprehension	-0.32	1.55	-5.43-4.00	1.01	2.01	-3.57-4.86	-4.713	150	<.001
LNS	-0.16	2.32	-5.86-4.43	-1.35	2.12	-8.50-3.00	3.335	154	.001
Picture Completion	0.02	2.04	-5.00-5.29	-0.45	1.77	-4.83-5.67	1.612	160	.109
Digit Symbol Coding	0.23	2.19	-5.00-6.29	-0.13	1.75	-4.83-3.33	1.143	160	.255
Block Design	-0.14	1.47	-3.71-3.00	0.56	1.83	-4.33-5.57	-2.710	160	.007
Matrix Reasoning	-0.19	1.89	-4.57-3.71	0.34	1.77	-3.50-4.00	-1.839	160	.068
Picture Arrangement	0.16	2.28	-4.71-8.43	-0.24	1.86	-4.83-4.33	1.512	159	.133
Symbol Search	0.08	1.88	-6.29-4.00	0.23	1.68	-3.43-5.17	-0.511	154	.610
	Weakness	Average	Strength	Weakness	Average	Strength			
Vocabulary	5 (6%)	71 (88%)	5 (6%)	3 (4%)	58 (72%)	20 (24%)			
Similarities	6 (7%)	71 (88%)	4 (5%)	6 (7%)	65 (80%)	10 (12%)			
Arithmetic	10 (12%)	64 (79%)	7 (9%)	14 (17%)	63 (78%)	4 (5%)			
Digit Span	6 (7%)	73 (90%)	2 (3%)	24 (30%)	53 (65%)	4 (5%)			
Information	3 (4%)	70 (86%)	9 (11%)	6 (7.5%)	69 (85%)	6 (7.5%)			
Comprehension	6 (7%)	72 (89%)	3 (4%)	2 (2%)	63 (78%)	16 (20%)			
LNS	5 (6%)	71 (88%)	5 (6%)	14 (19%)	61 (81%)	0 (0%)			
Picture Completion	7 (8%)	71 (88%)	3 (4%)	8 (10%)	71 (88%)	2 (2%)			
Digit Symbol Coding	3 (4%)	72 (89%)	6 (7%)	4 (5%)	77 (95%)	0 (0%)			
Block Design	1 (1%)	80 (99%)	0 (0%)	2 (2%)	72 (89%)	7 (9%)			
Matrix Reasoning	11 (14%)	64 (79%)	6 (7%)	3 (4%)	65 (80%)	13 (16%)			
Picture Arrangement	4 (5%)	73 (91%)	3 (4%)	2 (2.5%)	77 (95%)	2 (2.5%)			
Symbol Search	2 (2%)	74 (94%)	3 (4%)	0 (0%)	74 (96%)	3 (4%)			

Notes: LNS = Letter Number Sequencing

The frequency of strengths and weaknesses are presented at the second part of Table 6. Vocabulary and Comprehension appeared more frequently as strength for the mixed neurologic injured patients than for the matched controls. Table 6 also showed that the Matrix Reasoning subtest is frequently strength for the healthy control group and weaknesses for the mixed neurologic injured group.

DISCUSSION

All composite measures were statistically different between the two groups, but none of these differences had clinical relevance, because they were all within Wechsler's normal range classification. Only WMI had acceptable sensitivity and specificity values. Only two discrepancy scores (i.e., VIQ-PIQ and CVI-WMI) were statistically different between groups, but their sensitivity and specificity values demonstrated poor accuracy to discriminate between acquired brain injury patients from healthy controls. At the subtest level, all subtests scaled scores except Vocabulary and Comprehension were statistically different between groups, and again both groups had all mean scores within the normal range. Only Digit Span subtest had an acceptable diagnostic accuracy. Finally, different scatter (strengths/weakness) scores' profiles between the two groups were found for Digit Span, Letter Number Sequencing and Matrix Reasoning subtests. Taken together, the results of the present study failed to find a clinical useful profile for mixed neurologic

injury, because, even though there are significant differences among groups, all mean scores were within the normal range.

Many neuropsychologists use Digit Span and Letter Number Sequencing to assess frontal lobe dysfunction. In fact, MacPherson, Della Sala and colleagues (2015) presented the Digit Span backwards as a good test for assessing Working Memory. Although impossible to associate to a specific brain lesion, our data is consistent with the idea that Digit Span and WMI are acceptable measures to search for mixed neurologic injury.

Back to 1939, the Wechsler-Bellevue (W-B) Scale was constructed, and its "aim was not to produce a set of a brand new tests but to select, from whatever source available, such a combination of them as would best meet the requirements of an effective adult scale" (Wechsler, 1944, p.76). Since its beginning, a vast quantity of research consolidated the use of the various versions of the WAIS across clinical settings. However, the idea that Wechsler's measures have limited neuropsychological usefulness is not new. Forty years ago, John McFie (1975) once wrote that "it is perhaps a matter of luck that many of the Wechsler subtests are neurologically relevant. They are evidently not designed with this purpose in mind; yet it follows (…) that tests based on the major group factors of ability are likely to be sensitive to lesions in specific cerebral areas" (p.14). Thirteen years later, Lezak (1988) offered a funeral oration to the intelligence quotient (IQ) concept, but another twenty years passed and two of the most important neuropsychological assessment handbooks (Lezak, Howieson, Bigler, & Tranel, 2012; Strauss, Sherman, & Spreen, 2006) still report the survival of the Wechsler Adult Intelligence Scales as the most frequently used intelligence measure in the neuropsychological batteries.

Our study aimed to find the utility of the Portuguese WAIS-III on the assessment of cognitive impairments in brain lesioned patients with mixed neurologic diseases. The regression analysis unquestionably indicated that the presence of mixed neurologic injury, the age of disease onset, years of disease duration and literacy affected WAIS-III performance. The effects of literacy on WAIS performance were reported since its creation (Wechsler, 1944), and have been studied more recently for WAIS-III (Colom, Abad, Garcia, & Juan-Espinosa, 2002). In some countries other than Portugal, norm tables corrected for literacy can be purchased separately from the test manual. We tried to minimize literacy effects by matching controls in literacy. Still, the way literacy may function as a cognitive reserve on WAIS-III was not easy to interpret in our data. More detailed work is needed on this topic.

If mixed neurologic injury and literacy both influence WAIS-III performance, why didn't we find clinical useful differences? A logical argument is that different brain locations contribute differently to the same cognitive functions. Once there was no homogeneity for brain lesion locations in our sample, strength of one patient may be canceled by the weakness of another, and when we look at mean scores, some deficits may be masked by the group average. To avoid this study limitation, we suggest that future studies should plan their samples based on brain lesion location, rather than on brain diseases.

The first attempts to study brain locations with the various version of the WAIS, compared right *versus* left brain lesion. An exhaustive review of these studies was done by Kaufman and Lichtenberger (2006), who clearly revealed that the VIQ-PIQ discrepancy consistently predicted in which side of the brain the lesion took place, but only if the Wechsler-Bellevue Scale was used. With WAIS-III, Ryan, Bartels, Morris, Cluff, and Gontkovsky (2009) with a United States sample, and Gonçalves, Simões, and Castro-Caldas (2014a) with a Portuguese sample, failed the identification of lateralized lesions. Therefore, homogenous brain lesion location samples (e.g., Tranel, Manzel, & Anderson, 2008; Glascher et al., 2009) are needed to study the correlations of specific WAIS-III deficits with neurologic injuries in specific brain locations.

In sum, although WAIS-III performance is proved to be influenced by the presence of mixed neurologic injury, it may continuously fail to detect it if norms are not corrected for literacy and the research paradigm doesn't change from studying neurologic diseases to studying specific brain locations or specific cognitive impairments,.

We planned and searched for differences in this paper, but it turned out that one of the most important issues that emerged from our data was the issue of a non-significant statistical difference. Vocabulary turned out to have the same performance profile for the two groups, both at the scaled score and the scatter score levels of the analysis. This fact made Vocabulary a good candidate for a premorbid intelligence measure. What if Vocabulary alone could estimate the premorbid IQ? A large amount of time could be saved in the neuropsychological assessment and this could be a very useful clinical finding. This idea again is not new (Yates, 1956; Schoenberg, Lange, Marsh & Saklofske, 2011) and we're already working on this topic in a different paper.

In short, despite the small sample size, with a mixed of neurologic diseases and lack of homogeneity in brain lesion locations, our data reveals significant lower performance of the mixed neurologic injury group when compared to a matched healthy control group.

Multiple regression analysis confirms the presence of mixed neurologic injury as a predictor of the WAIS-III's IQs and Indexes. However, all mean scores were within the normal range, what would have made mixed neurologic injury stay unnoticed, even to an experienced neuropsychologist. Further work is needed in creating norms corrected for literacy and in redefining what is important in sample selection. It is our strong belief that we should abandon diseases' etiologies from the sample inclusion criteria, and start focusing on brain lesion locations as the key variable.

STUDY 4: LATERALIZED BRAIN LESION

Oral communication + Paper in preparation

Gonçalves, M.A., Castro-Caldas, A., & Simões, M.R. (2016, September). WAIS-III: Discriminação entre lesões hemisféricas direitas e esquerdas nas discrepâncias QIV-QIR E ICV-IOP. 3º Congresso da Ordem dos Psicólogos Portugueses, Porto, Portugal.

Titulo: **WAIS-III: DISCRIMINAÇÃO ENTRE LESÕES HEMISFÉRICAS DIREITAS E ESQUERDAS NAS DISCREPÂNCIAS QIV-QIR E ICV-IOP**

É assumido, desde os anos 40, que uma lesão cerebral hemisférica direita (HD) afetará mais as pontuações no QIR que no QIV, e uma lesão cerebral hemisférica esquerda (HE), o inverso. Com base numa amostra clínica (n=36), o estudo de Ryan, Bartels, Morris, Cliff e Gontkovsky (2009) concluiu que as discrepâncias QIV-QIR e ICV-IOP da WAIS-III não foram eficazes a lateralizar a lesão cerebral.

No presente estudo pretendeu-se verificar a utilidade das mesmas discrepâncias, num total de 130 participantes portugueses, subdivididos em duas amostras com lesão cerebral lateralizada (n lesão HD+HE = 31+34) e duas amostras controlo, retiradas da amostra de aferição e emparelhadas com as primeiras em idade, escolaridade e profissão (n controlo HD+HE = 31+34).

As diferenças entre as médias das discrepâncias QIV-QIR e ICV-IOP não foram estatisticamente significativas para nenhuma das comparações: lesão HD *versus* lesão HE ($p>.540$), lesão HD *versus* controlo HD ($p>.439$), lesão HE *versus* controlo HE ($p>.169$), nem controlo HD *versus* controlo HE ($p>.183$). Valores considerados "anormais" para QIV-QIR (>18) e para ICV-IOP (>21) aparecem com percentagens residuais nas amostras com lesão cerebral, mas também nas amostras controlo, sendo que algumas vezes, o valor da discrepância não segue o sentido esperado. Os valores de sensibilidade para as discrepâncias nos dois grupos com lesão cerebral lateralizada são todos inferiores a .52 ($p>.268$).

Os nossos resultados apoiam os de Ryan et al (2009), mostrando que as discrepâncias QIV-QIR e ICV-IOP não são eficazes em lateralizar a lesão cerebral.

INTRODUCTION

It has long been accepted that a lateralized brain lesion will be reflected in the VIQ-PIQ discrepancy, even if this thum rule doesn't appear in Wechler-Bellevue (Wechsler, 1944), WAIS (Wechsler, 1955, 1958) or WAIS-R (Wechsler, 1981) manuals. It is accepted that if VIQ>PIQ the brain lesion is expected in the right hemisphere, and if VIQ<PIQ, the brain lesion is expected in the left hemisphere (Kaufman, 1990; Gregory, 1999; Kaufman & Lichtenberger, 1999). Though, in a thorough review of the literature, Kaufman (1990) found that only 9 out of 33 studies corroborate this idea for WAIS and WAIS-R, when 17 out of 18 studies corroborated this idea for Wechsler-Bellevue.

With WAIS-III, Ryan, Bartels, Morris, Cluff, and Gontkovsky (2009) with a United States sample (n=36), and Gonçalves, Simões, and Castro-Caldas (2014b) with a Portuguese sample (n=32), failed the identification of lateralized lesions.

GOALS

(1) To explore the VIQ-PIQ and VCI-POI discrepancies in two samples of lateralized brain lesion (i.e., right *versus* left hemisphere lesions)

(2) To explore the same discrepancies in a lateralized brain lesion sample in comparison to a matched control group

METHOD

Participants were selected from mixed neurological sample described in the previous chapter. For more detailed information about the matching of demographic variables for sample selection and test administration procedures see previous chapter.

Right lesion group and right control group had 19 female participants (61.3%) and 12 male participants (38.7%) respectively. Left lesion group and left control group had 12 female participants (35.5%) and 22 male participants (64.7%) respectively.

Brain lesion etiologies were similar for right and left lesion groups. Right lesion group had 10 brain tumor patients (32.3%), 13 refractory epilepsy patients (41.9%), and 8 subarrachnoid hemorrhage and stroke patients (25.8%). Left lesion group had 10 brain tumor patients (32.3%), 11 refractory epilepsy patients (32.4%), and 13 subarrachnoid hemorrhage and stroke patients (38.2%).

T-test indicated age and literacy did not differ significantly for right lesion and left lesion groups (fist part of table 1), nor right control and left control groups (second part of table 1). Age and literacy did not differ for right lesion and right control groups, $T(60) = .127$, $p = .899$, and $T(60) = .381$, $p = .704$, respectively. Age and literacy did not differ for

left lesion and left control groups, T(66) = .187, p = .852, and T(66) = .290, p = .773, respectively

Table 1. Demographic information about
right lesion, left lesion, right control and left control groups

	Right lesion (n=31)			Left lesion (n=34)				
	M	SD	Range	M	SD	Range	T (63)	p
Age	49.81	15.153	22-76	53.29	16.765	22-80	-.877	.384
Literacy	9.65	4.666	4-17	8.76	4.856	0-17	.744	.460
	Right control (n=31)			Left control (n=34)				
	M	SD	Range	M	SD	Range	T (63)	p
Age	49.32	14.809	22-76	52.53	17.012	22-82	-.807	.423
Literacy	9.23	3.964	4.14	8.44	4.322	0-14	.760	.450

RESULTS

Four group comparisons (i.e., right *versus* left lesion, right control *versus* left control, right lesion *versus* right control and left lesion *versus* left control) for two discrepancies (i.e., VIQ-PIQ and VCI-POI) did not differ significantly as showed in table 2. Comparisons for VIQ, PIQ, VCI and POI scores can be found at Appendix 1 at the end of this chapter.

Table 2. Discrepancy scores for
right lesion, left lesion, right control and left control groups

	Right lesion (n=31)			Left lesion (n=34)					
	M	SD	Range	M	SD	Range	T	df	P
VIQ-PIQ	4.71	12.351	-22-37	2.71	14.044	-34-40	.608	63	.545
VCI-POI	5.97	13.634	-23-37	3.68	16.098	-34-40	.616	63	.540
	Right control (n=31)			Left control (n=34)					
	M	SD	Range	M	SD	Range	T	df	p
VIQ-PIQ	2.29	12.122	-24-23	-1.52	10.450	-29-18	1.348	62	.183
VCI-POI	3.87	12.273	-19-27	2.26	12.273	-30-33	.510	63	.612
	Right lesion (n=31)			Right control (n=31)					
	M	SD	Range	M	SD	Range	T	df	P
VIQ-PIQ	4.71	12.351	-22-37	2.29	12.122	-24-23	.778	60	.439
VCI-POI	5.97	13.634	-23-37	3.87	12.273	-19-27	.617	60	.540
	Left lesion (n=34)			Left control (n=34)					
	M	SD	Range	M	SD	Range	T	df	P
VIQ-PIQ	2.71	14.044	-34-40	-1.52	10.450	-29-18	1.392	65	.169
VCI-POI	3.68	16.098	-34-40	2.26	12.273	-30-33	.407	66	.686

Using the same cutt-off points used by Ryan et al (2009), frequency counting and percentages were calculated. As showed in Table 3, non-significant points for either discrepancy (i.e., VIQ-PIQ and VCI-POI) for all groups were near or above half sample (from 48.5% to 63.6%), and abnormal points had residual frequencies (less than 16.1%). Discrepancies have similar distribution for the lesion groups when compared to their matched control groups, exception made for VIQ-PIQ discrepancy and the left groups. VIQ-PIQ discrepancy has more reliable and abnormal discrepancies for the left lesion group than for its matched control, however it was expected that VIQ<PIQ and the results showed a higher frequency for VIQ>PIQ (17.6%) than for VIQ<PIQ (8.8%). Right lesion was expected to have VIQ>PIQ and VCI>POI, but frequencies for these results are similar among right and left lesion groups, repectively 16.1% and 17.6% for VIQ-PIQ and 12.9% and 11.8% for VCI-POI respectively. Last but not the least, it is worth noting that sometimes the control groups have higher frequency of abnormal points than the lesion groups (i.e., VIQ-PIQ and VCI-POI discrepancies, both for the right groups).

Table 3. VIQ-PIQ e VCI-POI discrepancy scores for
right lesion, left lesion, right control and left control groups

VIQ-PIQ	Non-significant	Reliable (≥9)		Abnormal (≥19)	
	(≤8)	V>P	V<P	V>P	V<P
Right lesion	15 (48.4%)	12 (38.7%)	4 (12.9%)	5 (16.1%)	1 (3.2%)
Right ctrl	16 (51.6%)	11 (35.5%)	4 (12.9%)	3 (9.7%)	2 (6.5%)
Left lesion	18 (52.9%)	10 (29.4%)	6 (17.6%)	6 (17.6%)	3 (8.8%)
Left ctrl	21 (63.6%)	6 (18.2%)	6 (18.2%)	0 (0%)	1 (3.0%)
VCI-POI	Non-significant	Reliable (≥10)		Abnormal (≥22)	
	(≤9)	V>P	V<P	V>P	V<P
Right lesion	16 (51.6%)	12 (38.7%)	3 (9.7%)	4 (12.9%)	1 (3.2%)
Right ctrl	18 (58.1%)	10 (32.3%)	3 (9.7%)	5 (16.1%)	0 (0%)
Left lesion	17 (50.0%)	12 (35.3%)	5 (14.7%)	4 (11.8%)	2 (5.9%)
Left ctrl	19 (55.9%)	11 (32.4%)	4 (11.8%)	2 (5.9%)	1 (2.9%)

The results from the ROC curve analysis showed that neither VIQ-PIQ nor VCI-POI discrepancies was relevant measure for discriminating between right and left lesions, with AUC values varying from .511 to .515 for the right lesion group and values varying from .426 to .452 for the left lesion group.

Table 4. Sensitivity for VIQ-PIQ and VCI-POI discrepancies for the right lesion, left lesion groups

	VIQ-PIQ		VCI-PIQ	
	AUC	p	AUC	p
Right lesion (n=31)	.511	.876	.515	.819
Left lesion (n=34)	.426	.268	.452	.470

CONCLUSIONS AND DISCUSSION

No diferences were found for mean VIQ-PIQ and VCI-POI discrepancies for any of the four group comparisons made. No clinically usefull abnormal points or sensitivity scores were found. Taking all these results together, they corroborate Ryan et al (2009) and Kaufman (1990) idea that these discrepancies are no longer useful for the clinical discrimination of lateralized brain lesions.

Appendix 1.

Scaled scores for right lesion, left lesion, right control and left control groups

	Right lesion (n=31)			Left lesion (n=34)			T	df	p
	M	SD	Range	M	SD	Range			
VIQ	98.39	14.221	67-122	96.71	16.734	67-127	.434	63	.666
PIQ	94.06	18.201	53-123	94.00	18.424	61-148	.014	63	.989
VCI	101.74	14.285	70-129	99.32	16.584	70-134	.627	63	.533
POI	95.58	18.244	54-127	95.65	17.310	69-144	-.015	63	.988
	Right control (n=31)			Left control (n=34)			T	df	p
	M	SD	Range	M	SD	Range			
VIQ	106.32	10.971	79.125	105.06	15.293	68-133	.379	63	.706
PIQ	104.03	15.592	70-127	106.91	17.445	69-141	-.694	62	.490
VCI	107.65	11.476	70-129	106.74	15.609	70-134	.266	63	.791
POI	104.93	14.275	54-127	104.47	18.785	69-144	.100	62	.913
	Right lesion (n=31)			Right control (n=31)			T	df	P
	M	SD	Range	M	SD	Range			
VIQ	98.39	14.221	67-122	106.32	10.971	79.125	-2.460	60	.017
PIQ	94.06	18.201	53-123	104.03	15.592	70-127	-2.316	60	.024
VCI	101.74	14.285	70-129	107.65	11.476	70-129	-1.794	60	.078
POI	95.58	18.244	54-127	104.93	14.275	54-127	-2.225	59	.030
	Left lesion (n=34)			Left control (n=34)			T	df	P
	M	SD	Range	M	SD	Range			
VIQ	96.71	16.734	67-127	105.06	15.293	68-133	-2.149	66	.035
PIQ	94.00	18.424	61-148	106.91	17.445	69-141	-2.943	65	.005
VCI	99.32	16.584	70-134	106.74	15.609	70-134	-1.898	66	.062
POI	95.65	17.310	69-144	104.47	18.785	69-144	-2.014	66	.048

STUDY 5: VOCABULARY

Gonçalves, M.A., Simões, M.R., & Castro-Caldas, A. (2016, February). *WAIS-III's Vocabulary holds as a good measure of premorbid functioning after brain injury*. Poster presented at the INS 44th Annual Meeting, Boston, Massachussets, USA.

TITLE: WAIS-III's Vocabulary holds as a good measure of premorbid functioning after brain injury

ABSTRACT:

Objective : To explore the Portuguese version of the Wechsler Adult Intelligence Scale 3rd edition (WAIS-III) in a series of patients with brain injury.

Participants and Methods: A mixed neurological sample of 81 brain injured patients (23 brain tumor, 30 refractory epilepsy pre/post-surgery, 20 subarachnoid hemorrhage, 4 stroke, and 4 traumatic brain injury) and 81 demographically matched healthy individuals performed the Portuguese WAIS-III (Wechsler, 2008). T-test for independent samples and ROC curves were used for data analyses.

Results: The mean scaled scores of Vocabulary ($p=.402$) and Comprehension ($p=.427$) were similar between groups. On the remaining 11 subtests, the healthy control group had significantly better scaled scores than the neurological group ($p<.05$). The neurological and the healthy control groups' percentages of scaled scores above six were respectively 94% and 91% for Vocabulary and 85% and 94% for Comprehension. For the remaining subtests, the percentage of scaled scores above six ranged from 63% to 81% for the neurological group and from 86% to 96% for the control group. ROC curves showed the lowest score for Comprehension (AUC=.527), followed by Vocabulary (AUC=.554). The remaining AUC scores ranged from .610 to .755.

Conclusions: The results support a long tradition of using Vocabulary as a measure of premorbid intelligence that started with Yates (1956) and is still in use with WAIS-III (Schoenberg et al, 2011). It also reinforces the cross-cultural interest of this measure.

BACKGROUND

A neuropsychological assessment includes a premorbid measure, and in most of the cases, this measure is an intelligence test.

WAIS-III was standardized to the Portuguese population in 2008, and its clinical validation has being done since then.

GOAL

To explore the Portuguese version of the Wechsler Adult Intelligence Scale 3rd edition (WAIS-III) in a series of patients with brain injury.

METHOD

The participants were 81 healthy controls and 81 brain lesioned patients with mixed neurologic diseases matched for gender (37 female and 44 male), age, literacy (completed years of formal education), professional status and geographic region. Table 1 shows the descriptive statistics for age, literacy, age at disease onset and years of disease duration. For more detailed information about demographic variables and test administration procedures see last but one chapter.

Table 1 Demographics

	Age-Matched Controls (N=81)			Mixed Neurological Disorder (N=81)				
	Mean	SD	Range	Mean	SD	Range	T (160)	p-value
Age	49.05	16,03	22-82	49.68	16,01	21-80	-0.250	.803
Literacy	8.90	4.03	0-14	9.23	4,60	0-17	-0.490	.625
Age onset				36.96	21.97	0-77		
Duration (years)				12.59	14.03	0.03-63		

RESULTS

Main results:

1. Table 2 shows no mean differences among groups for Vocabulary and Comprehension.
2. Table 3 shows chance level at AUC ROC curves for Vocabulary and Comprehension
3. Table 4 shows 94% of the clinical group have normal scaled score (score $\geq$ 7) in Vocabulary.

Other important results:

4. Vocabulary had good correlations with Verbal IQ (VIQ), Full Scale IQ (FSIQ) and Verbal Comprehension Index (VCI) as showed in Table 5

Table 2. Mean scaled scores

	Matched controls (N=81)			mixed neurologic (N=81)					
	Mean	SD	Range	Mean	SD	Range	t	*df*	*p*
Vocabulary	11.12	3.12	3-16	10.73	2.87	4-17	0.840	160	.402
Similarities	10.84	2.71	5-17	9.46	3.45	1-17	2.835	152	.005
Arithmetic	10.77	3.10	4-16	8.49	3.23	1-15	4.566	159	<.001
Digit Span	10.81	2.68	5-19	8.27	3.19	3-17	5.499	160	<.001
Information	11.79	3.11	4-19	9.67	3.38	3-17	4.164	160	<.001
Comprehension	10.68	2.77	4-10	10.30	3.32	3-17	0.797	160	.427
Letter Number Sequencing	10.81	3.26	4-17	8.33	2.86	3-14	4.975	151	<.001
Picture Completion	10.81	3.04	4-17	8.27	3.41	1-15	5.009	160	<.001
Coding	11.01	3.39	4-17	8.59	3.55	2-19	4.436	160	<.001
Block Design	10.64	3.13	4-18	9.31	3.53	2-18	2.543	160	.012
Matrix Reasoning	10.59	3.13	4-19	9.09	3.34	2-19	2.962	160	.004
Picture Arrangement	10.98	3.18	3-17	8.41	2.97	2-16	5.294	159	<.001
Symbol Search	10.82	2.99	3-16	9.11	3.60	2-19	3.235	153	.001

Table 3. ROC curves for each subtest with the whole sample

	Sensitivity	Specificity	Optimal cut-off	Youden Index J	AUC
Vocabulary	46.9	67.9	≤ 10	.148	.554
Similarities	51.9	76.5	≤ 9	.284	.621
Arithmetic	65.0	69.1	≤ 9	.341	.694
Digit Span	54.3	82.7	≤ 8	.370	.736
Information	61.7	67.9	≤ 10	.296	.680
Comprehension	9.9	98.8	≤ 5	.086	.527
LNS	65.3	68.7	≤ 9	.340	.715
Picture Completion	76.5	54.3	≤ 10	.308	.708
Digit Symbol Coding	60.5	71.6	≤ 9	.321	.696
Block Design	72.8	45.7	≤ 11	.185	.610
Matrix Reasoning	71.6	48.1	≤ 10	.197	.630
Picture Arrangement	54.3	81.2	≤ 8	.355	.723
Symbol Search	73.7	57.0	≤ 10	.306	.660

Table 4. Percentages of scaled scores <7 and >6

	Matched controls (N=81)		mixed neurologic (N=81)	
	<7	>6	<7	>6
Vocabulary	9%	91%	6%	94%
Similarities	7%	93%	19%	81%
Arithmetic	11%	89%	32%	68%
Digit Span	4%	96%	37%	63%
Information	4%	96%	23%	77%
Comprehension	6%	94%	15%	85%
Letter Number Sequencing	11%	89%	31%	69%
Picture Completion	10%	90%	32%	68%
Coding	12%	88%	30%	70%
Block Design	14%	86%	26%	74%
Matrix Reasoning	9%	91%	20%	80%
Picture Arrangement	9%	91%	25%	75%
Symbol Search	9%	91%	22%	78%

Table 5. Pearson's correlations with VIQ, FSIQ and VCI

	Matched controls (N=81)			mixed neurologic (N=81)			
	VIQ	FSIQ	VCI	VIQ	FSIQ	VCI	*p*-value
Vocabulary	.877	.867	.880	.879	.757	.896	<.001
Comprehension	.845	.787	.759	.823	.732	.757	<.001

DISCUSSION

Our results support the old tradition reported by Schoenberg, Lange, Marsh & Saklofske (2011) and Lezak, Howieson, Bigler & Tranel (2012) of using Vocabulary as a measure of premorbid intelligence.

Small sample and the heterogeneity of etiologies and lesion locations can be noted as limitations. However, the most important limitation of this study is that the Vocabulary-FSIQ correlation is good but not as high for the clinical group as for the control group. Therefore, Vocabulary was found to be a good premorbid measure for VIQ and VCI, but FSIQ premorbid estimations should be seen with caution.

STUDIES 6 AND 7: SHORT FORM

Gonçalves, M.A., Simões, M.R., & Castro-Caldas, A. (2015, November). Ward's seven subtest short-form of the WAIS-III for brain lesion patients. In Marcelino Pereira (chair), *Avaliação neuropsicológica aplicada*, symposium conducted at the 3º Congresso Internacional do CINEICC/1º Congresso da APTC, Coimbra, Portugal.

and

Gonçalves, M.A., Simões, M.R., & Castro-Caldas, A. (submitted). Ward's subtest short-form of the WAIS-III for patients with drug resistant epilepsy

STUDY 6:

Ward's seven subtest short-form of the WAIS-III for brain lesion patients

ABSTRACT:

Introduction: WAIS-III is the most used battery of intelligence in a neuropsychological assessment. Establishing a reliable and valid short form of this battery can save long time in the assessment of brain injured patients.

Methods: Eighty-one mixed neurological brain injured patients (30 epileptic, 23 brain tumor, 20 subarachnoid hemorrhage, 4 stroke and 4 traumatic brain injury) and 30 consecutive refractory epileptic patients isolated from the whole mixed clinical sample were administered the Portuguese full form WAIS-III. Four abbreviation versions of the seven-subtest short form (Ward, 1990) were calculated and compared: *weighed versus prorated* formulas, *Block Design versus Matrix Reasoning* subtests.

Results: All versions proved adequate for the IQs estimations for the mixed neurological group, but only the *weighted* formula proved adequate for the epileptic group. Correlations between full form and the *weighted* short form VIQ, PIQ and FSIQ scores ranged from .95 to .99, for both groups. However, accuracy scores showed some weaknesses of the IQs estimations for both groups. Accuracy scores also showed a superiority of the *Block Design* version over the *Matrix Reasoning* version.

Discussion: The correlations between full form and estimated IQs pointed to the weighted Block Design formula as the best seven subtest short form, though accuracy scores reveal some weaknesses of this measure.

Conclusion: This study support limited use of WAIS-III short forms when conducting neuropsychological assessment in general. This study also support limited use of WAIS-III short forms when conducting pre-surgical evaluations of refractory epilepsy patients, but it supports the use of the abbreviated version when conducting the repetitive follow-up evaluations.

KEY-WORDS:

WAIS-III, short form, seven subtest short form, Ward’s short form

STUDY 7:

Ward's seven subtest short-form of the WAIS-III for patients with drug resistant epilepsy

Abstract

PURPOSE: WAIS-III is a battery of intelligence subtests frequently used in the pre- and post-surgical assessment of refractory epilepsy patients. Establishing a reliable and valid short form of this battery can save long time in the repeated psychological evaluations of these patients. METHODS: Thirty consecutive refractory epileptic patients and 30 healthy matched controls were administered the Portuguese full form WAIS-III. Four abbreviated versions of the seven-subtest Ward' short form (i.e., weighed *versus* prorated formulas with either Block Design *versus* Matrix Reasoning subtests) were calculated and compared. RESULTS: All versions proved to be adequate for the estimation IQs for healthy controls, but only the weighted formula proved adequate for the epileptic group. Correlations between the VIQ, PIQ and FSIQ scores from the weighted short form and full form ranged from .95 to .99 both, however accuracy scores showed some weaknesses of some IQs estimations. CONCLUSION: This study encourages the use of WAIS-III short-forms when conducting post-surgical evaluation of refractory epilepsy patients, but not when conducting the pre-surgical evaluation.

Highlights:

- Estimated IQs are similar to real IQs for the control group, and slighted underestimated for the epileptic group
- Both groups had all estimated IQ and real IQ Pearson's correlations higher than .90 for the two versions of the weighted formula
- Although not perfect, accuracy analysis showed acceptable results
- WAIS-III short-forms are discouraged in pre-surgery, but are welcome in the follow-up
- WAIS-III short-forms have different psychometric properties when validation sample varies

Key-words: Refractory epilepsy; Epilepsy surgery; Wechsler Adult Intelligence Scale third edition; Seven-subtest; Intelligence

INTRODUCTION

The neuropsychological evaluation protocols used, before and after surgery, in the cases of patients with refractory epilepsy (e.g., Berg et al, 2003) usually include the Wechsler Adult Intelligence Scales (WAIS). However the full administration of the WAIS alone can take up to two hours with clinical samples (Wechsler, 2008; Ryan, Lopez & Werth, 1998), and therefore the remaining assessment must be scheduled for another day, or it can be compromised when it should not be. Moreover, administering the WAIS-III full form (11 to 14 subtests) is sometimes not feasible in clinical practice due to patient's fatigue or frustration. The influence of fatigue on neuropsychological test performance is well documented (e.g., Sytober & DeLuca, 2013). Fatigue also seems to be a common symptom observed in epilepsy. Moreover three fatigue scales differentiate people with epilepsy from healthy controls, with epilepsy patients reporting higher scores across all the measures (Hernandez-Ronquillo, Moien-Afshari, Knox, Britz, & Tellez-Zentenon, 2011). So, a good choice for saving time could be the use of a WAIS-III' short-form, validated for epileptic patients, which could estimate the three IQ, with a good reliability, in considerably less time than needed to do the full form.

There are two possible ways to create a Wechsler Intelligence Scale' short-form, one is reducing the number of items per subtest (e.g., the Staz-Mogel short-form) and the other is reducing the number of subtests. For the purpose of this study, we only focused in short-forms that abbreviated the number of subtests. The most common these abbreviations use four subtests (tetrads), but they will only estimate Full Scale IQ (e.g., Donnell, Pliskin, Holdnack, Axelrod, & Randolph, 2007; Schrimsher, O'Bryan, O'Jile & Sutker, 2008; Gregoire & Wierzbicki, 2009, Reid-Arndt, Allen & Schoop, 2011). There are also abbreviations with eight subtests to estimate the four Indexes, but not the three IQs (e.g., Donders & Axelrod, 2002; Lange, Iverson, Viljoen, & Brink, 2007). Therefore we chose to put our focus specifically on Ward's seven-subtest short-form, because as far as the authors are aware, this is the only abbreviation that estimates Verbal IQ (VIQ), Performance IQ (PIQ) and Full Scale IQ (FSIQ) separately.

The Ward' short-form was originally created to abbreviate the WAIS-R (Ward, 1990), but it is also studied for WAIS-III, WAIS-IV (Meyers, Zellinger, Knockler, Wagner, & Miller, 2013) and WISC-IV (McKenzie, Murray, Murray, & Murray, 2014; Hrabok, Brooks, Fay-McClymont, & Sherman, 2014). The Ward's WAIS-III' short-form is validated for several adult samples, namely, the US standardization sample (Ryan &

Ward, 1999), Learning Disabilities and Attention Deficit Hiperactivity Disorder samples (Wymer, Rayls, & Wagner, 2003), geriatric samples (Wymer, Rayls & Wagner, 2003; Brooks & Weaver, 2006), Traumatic Brain Injury sample (Scoop, Herman, Johnstone, Callahan, & Roudebush, 2001), and several samples of patients with mixed neuropsychiatric diagnosis (Axelrod, Ryan, & Ward, 2001; Pilgrim, Meyers, Bayless, & Whetstone, 1999; Kulas & Axelrod, 2002; Girard, Axelrod, & Wilkins, 2010).

The goal of the present study was to validate four versions of the Ward' seven-subtest WAIS-III short-form (a) for a Portuguese refractory epilepsy group, and (b) for a group of healthy matched controls; according to the three criteria usually used to judge the usefulness of a short form (Silverstein, 1985): (1) estimated IQ should not differ significantly from the full scale IQ, (2) correlation between a short form and the full form should be highly significant, and (3) the percentage of disagreement between a short form and the full scale should not be so high as to negate the usefulness of the short form.

METHODS

Participants

After institutional review board approval, patients were recruited at the Hospital de Santa Maria, Portugal, and written informed consent was obtained from all participants. Thirty consecutive participants with medically refractory epilepsy undergoing pre- or post-neurosurgical evaluation and 30 healthy matched controls (Table 1) were studied prospectively, from November 2012 to July 2014. Matched controls were selected from the Portuguese WAIS-III/WMS-III' standardization sample to match the clinical sample in gender, age, education, professional attainment and region of address.

Table 1. Clinical and demographic characteristics
for the epileptic and matched control groups

	Matched controls (N=30)			Epilepsy (N=30)				
	Mean	SD	Range	Mean	SD	Range	T	*p*
Age (years)	39.73	12.05	22-62	40.10	12.47	22-63	-0.116	.908
Literacy	9.43	3.41	4-14	9.43	3.75	4-17	0.000	1.000
Age at seizure onset (years)				15.25	10.48	0-34		
Duration of epilepsy (years)				24.27	15.23	1-63		
	n	%		n	%			
Gender (male)	15	50		15	50			
Right-handed				28	93.3			
Mesial temporal lobe epilepsy				23	76.6			
Right/Left Hemisphere				13/11	43/37			
Pre-/Post-surgery				25/5	83/17			

Measures and procedures

The Portuguese WAIS-III was administered and scored according to the manual procedures. Only psychologists with extensive experience in psychological assessment administered tests. All participants were administered the full form WAIS-III, and full form's scaled scores on composite measures and on each subtest are presented in Table 2. Significant differences between groups were found for all scaled scores, except Comprehension and Vocabulary subtests ($p > .01$).

Table 2. Means comparison for scaled scores
for the epileptic and the matched control groups

	Matched controls (N=30)			Epileptic (N=30)				
	Mean	SD	Range	Mean	SD	Range	T	*p*-value
IQ Scores								
VIQ	100.83	14.206	68-128	89.13	13.761	67-118	3.240	.002
PIQ	102.60	17.953	69-141	89.07	18.194	53-123	2.900	.005
FSIQ	101.70	16.942	66-137	87.87	16.606	58-123	3.194	.002
Verbal Subtests								
Vocabulary	10.27	3.300	3-16	9.30	2.322	5-14	1.312	.195
Similarities	10.23	2.812	5-16	8.63	3.068	1-14	2.106	.040
Arithmetic	10.07	3.017	5-15	7.40	2.966	2-14	3.400	.001
Digit Span	10.30	2.409	6-15	7.13	2.569	3-14	4.924	<.001
Information	10.20	3.033	4-15	7.87	2.0801	3-14	3.096	.003
Comprehension	9.97	2.798	4-16	9.30	2.926	3-13	0.902	.371
Letter Number Sequencing	10.47	2.751	4-16	7.36	2.531	3-13	4.323	.000
Performance subtests								
Picture Completion	10.27	2.924	4-15	8.60	3.663	1-15	1.948	.056
Digit Symbol Coding	10.97	3.518	4-14	8.10	3.199	2-15	3.302	.002
Block Design	10.17	3.260	4-18	8.47	3.748	2-15	1.874	.066
Matrix Reasoning	10.53	3.224	4-16	8.57	3.025	2-14	2.436	.018
Picture Arrangement	10.53	3.803	3-17	8.03	2.895	3-13	2.865	.006
Symbol Search	11.07	3.118	4-15	8.77	3.386	2-18	2.643	.011

Data for short-forms was obtained by re-scoring the original full WAIS-III protocol. Four different short-form versions were created according to the original *weighted formula* (Ward, 1990), the *modified formula* (Ryan & Ward, 1999) and the *prorated formula* (Axelrod, Ryan & ward, 2001, Kulas & Axelrod, 2002). Full form IQs (i.e., VIQ, PIQ and FSIQ) were compared to the respective estimated VIQ, PIQ and FSIQ.

For creating a short-form, first raw scores for the estimated Verbal and Performance IQ, respectively Vsum and Psum, were calculated according to the formulae below. Second, raw score for the estimated FSIQ or FSsum was calculated by adding Verbal raw score (Vsum) and Performance raw score (Psum), just like the manual prescribes for the full form. Finally, estimated scaled scores (i.e., estimated VIQ, PIQ and FSIQ) were calculated in the usual way from the tables in the manual.

The seven subtests chosen in the original formula (Ward, 1990) were Information (I), Digit Span (DS), Arithmetic (A), Similarities (Si), Picture Completion (PC), Block Design (BD), and Digit Symbol Coding (Cod). The *modified short-form* (Ryan & Ward, 1999) is identical to the original, except that Matrix Reasoning (MR) is substituted for Block Design within the Performance Scale. Then, raw scores for the estimated Verbal and Performance IQs were calculated using the following formulae:

- Weighted BD Vsum = Weighted MR Vsum = 2 x (I + Si) + DS + A
- Weighted BD Psum = 2 x (PC + BD) + Cod
- Weighted MR Psum = 2 x (PC + MR) + Cod
- Prorated BD Vsum = Prorated MR Vsum = (I + Si + DS + A) x 6/4
- Prorated BD Psum = (PC + BD + Cod) x 5/3
- Prorated MR Psum = (PC + MR + Cod) x 5/3

Statistical Analyses

To test the quality of the short-form estimations repeated measures analyses of variance and correlations between the short-form and the full form scores were performed (Table 2). To protect Type I error rate when performing multiple comparisons, significance was set at $p < .01$.

Clinical accuracy was calculated in two ways. First, (a) by calculating the percentages of discrepancy between full form minus estimated scores that stayed within five point intervals (Table 3) and second, (b) by calculating the percentage of short-form scores that stayed within the same Wechsler's qualitative descriptions (Table 4). Respectively, what we called (a) the discrepancy (Table 3) and (b) the classification (Table 4) scores were always calculated by subtracting the estimated score from the real score, though positive scores suggest underestimations and negative scores suggest overestimations.

According to the test manual, Wechsler's (2008) qualitative descriptions are related to ranges or intervals of performance. The ranges are: (1) Extremely Low (standard score < 70); (2) Borderline (standard score = 70-79); (3) Low Average (standard score = 80-89); (4) Average (standard score = 90-109); (5) High Average (standard score = 110-119); (6) Superior (standard score = 120-129); and (7) Very Superior (standard score > 130).

RESULTS

Reliability and validity data for the short-forms are provided in Table 3. The control sample had the estimated VIQ, the estimated PIQ and the estimated FSIQ similar to all the real IQs. The epileptic sample had similar real and estimated *weighted/prorated* PIQ and *weighted* FSIQ, but an underestimated *weighted/prorated* VIQ and *prorated* FSIQ. However these underestimations are clinically irrelevant, because all estimated scores

stayed within the same clinical qualitative description defined by Wechsler (2008), in this case the classification of an average standard score.

Pearson correlations between the full form and the short-form VIQ, PIQ and FSIQ scores are also presented in Table 3. All correlations were highly significant at $p < .001$. Correlations ranged from .931 to .986 for the control group and from .799 to .986 for the epileptic group. Moreover, all *weighted* short-forms met or exceeded the criterion of $r > .90$ reliability for all IQ combinations for either group, but *prorated* versions failed to exceed the criterion $r > .90$ reliability for the PIQ estimations for the epileptic group.

A discrepancy below six (i.e., within a five point interval) would be also considered a good accuracy, and a discrepancy below one would be considered the perfect accuracy. As highly desirable, the large majority of the control group's VIQ, PIQ and FSIQ discrepancies and all the epileptic group's PIQ discrepancies are below one (check Mean and SD columns from Table 4), but the epileptic group's VIQ and FSIQ discrepancies tend to vary from 1.27 to 3.00. Although not perfect, these mean results still showed a good accuracy. However, if we count the number of participants that felt within each 5 point interval instead of comparing mean scores, the accuracy decreases (check percentages columns from Table 4). VIQ and FSIQ had high percentages of good accuracies (i.e., discrepancy ≤ 5) ranging from 87 to 97% for the control group and ranging from 80 to 90% for the epileptic group. However, PIQ discrepancies had lower percentages of good accuracy scores ranging from 53 to 80%, for either group. Additionally, unacceptable accuracy scores (i.e., ≥ 10 points) are rare for VIQ and FSIQ estimations, but not so rare for PIQ estimations, again for either group. Detailed frequency information can be found in Appendix 1.

The other accuracy analysis run in this study was calculated according to Wechsler's qualitative descriptions, and it is shown in Table 5 and Appendix 2. Again, (1) the control group had higher percentage of exact classification scores than the epileptic group, (2) the PIQ estimations were the least accurate among the three IQ estimations for the control group and (3) the PIQ estimations had unacceptable accuracy scores (i.e., percentages higher than two points) for the epileptic group.

Table 3. Reliability and validity measures for short-forms estimates of VIQ, PIQ and FSIQ

	VIQ					PIQ					FSIQ				
Controls (n=30)	M	SD	Z	*p*	*r*	M	SD	Z	*p*	*r*	M	SD	Z	*p*	*r*
Full form	100.83	14.21				102.60	17.95				101.70	16.94			
Weighted BD	101.03	14.17	-0.593	.553	.978	101.87	18.44	-0.530	.596	.951	101.40	16.79	-0.185	.853	.981
Weighted MR	101.03	14.17	-0.593	.553	.978	102.93	17.48	-0.265	.791	.947	101.83	16.42	-1.213	.225	.986
Prorated BD	101.30	13.90	-0.766	.444	.975	102.53	18.31	-0.091	.927	.931	101.83	16.12	-0.610	.542	.978
Prorated MR	101.30	13.90	-0.766	.444	.975	103.50	17.22	-0.930	.352	.955	103.10	16.44	-0.273	.785	.940
Epilepsy (n=30)															
Full form	89.13	13.76				89.07	18.19				87.87	16.16			
Weighted BD	86.90	15.16	-2.620	.009	.960	89.40	20.52	-0.776	.438	.975	86.60	18.22	-1.902	.057	.986
Weighted MR	86.90	15.16	-2.620	.009	.960	89.80	19.03	-0.903	.366	.951	86.57	17.34	-2.095	.036	.975
Prorated BD	86.13	14.64	-3.250	.001	.959	89.00	20.21	-0.175	.861	.849	85.77	17.91	-3.255	.001	.946
Prorated MR	86.13	14.64	-3.250	.001	.959	89.37	18.75	-0.598	.550	.799	85.83	17.19	-2.950	.003	.929

Table 4. Mean, SD and Percentages of discrepancy scores (full form score – short-form score) of VIQ, PIQ and FSIQ

	VIQ					PIQ					FSIQ				
Controls (n=30)	M	SD	% ≤5	% 6-9	% ≥10	M	SD	% ≤5	% 6-9	% ≥10	M	SD	% ≤5	% 6-9	% ≥10
Weighted BD	-0.20	2.95	97	3	0	0.73	5.69	70	20	10	0.30	3.33	93.3	6.7	0
Weighted MR	-0.20	2.95	97	3	0	-0.33	5.79	67	20	13	-0.13	2.81	97	3	0
Prorated BD	-0.47	3.15	87	13	0	0.07	6.77	53	30	17	-0.13	3.57	90	10	0
Prorated MR	-0.47	3.15	87	13	0	-0.90	5.35	67	23	10	-1.40	5.81	87	10	3
Epilepsy (n=30)															
Weighted BD	2.23	4.30	80	13.3	6.7	-0.33	4.92	80	16.7	3.3	1.27	3.33	86.7	13.3	0
Weighted MR	2.23	4.30	80	13.3	6.7	-0.73	5.91	66.7	20	13.3	1.30	3.90	83.3	10	6.7
Prorated BD	3.00	4.15	86.7	13.3	0	0.07	4.68	53.3	30	16.7	2.10	3.21	90	10	0
Prorated MR	3.00	4.15	86.7	13.3	0	-0.30	5.44	66.7	13.3	10	2.03	3.85	86.7	10	3.3

Table 5. Percentage of accuracy according to Wechsler (2008) classification

	VIQ			PIQ			FSIQ		
Controls (n=30)	% exact	% ±1	% +2	% exact	% ±1	% +2	% exact	% ±1	% +2
Weighted BD	80	20	0	66.7	30	3.3	86.7	13.3	0
Weighted MR	80	20	0	63.3	36.7	0	80	20	0
Prorated BD	90	10	0	56.7	40	3.3	83.3	16.7	0
Prorated MR	90	10	0	63.3	36.7	0	70	26.7	3.3
Epilepsy (n=30)									
Weighted BD	63.3	36.7	0	73.3	23.4	3.3	76.7	23.3	0
Weighted MR	63.3	36.7	0	73.3	23.4	3.3	73.3	26.7	0
Prorated BD	56.7	43.3	0	73.3	26.7	0	73.3	26.7	0
Prorated MR	56.7	43.3	0	80.0	20	0	73.3	26.7	0

DISCUSSION

The present study demonstrated that if time is scarce and WAIS-III IQ scores are needed, the *weighted* version of the Ward' Seven-Subtest Short-Form of WAIS-III can be used with refractory epilepsy patients and healthy controls as well. However, the clinician must keep in mind that for the epileptic group, the VIQ and the FSIQ scores can be underestimated, and the PIQ estimation scores can be misleading in term of accuracy.

Overestimations are more commonly reported than underestimations among the WAIS short-forms (e.g., Hilsabeck, Schrager & Gouvier, 1999), but underestimated IQs were also found on seven-subtest short form studies (Brooks & Weaver, 2006; Kulas & Axelrod, 2002). Our results have showed a significant underestimation only for the epileptic group, and only for weighted/prorated VIQ and prorated FSIQ estimations. We don't have a clear justification for these IQs underestimations, but we could risk this might be due to the subtest selection. As shown in Table 2, although irrelevant for the purpose of clinical classification according to Wechsler's qualitative descriptions, the epileptic group had a significant lower performance on all subtests used to calculate the Ward' short-forms.

Although mean discrepancy scores suggest a superiority of the Block Design version over the Matrix Reasoning version, accuracy percentages support the idea that there is no virtual difference between Block Design and Matrix Reasoning versions, as described by previous studies (Ryan & Ward, 1999; Schoop, Herman, Johnstone, Callahan, & Roudebush, 2001; Kulas & Axelrod, 2002).

Previous studies (Kulas & Axelrod, 2002; Hilsabeck, Schrager, & Gouvier, 1999, Iverson, Myers & Adams, 1997) also showed virtually no difference between the *prorated*

and the *weighted* versions, and same happens in our study, but only for the healthy control group. Against this finding, the epileptic group showed differences between the *weighted* and the *prorated* versions, moreover the *prorated* version failed to have acceptable correlations with the full form PIQ, and this invalidated the *prorated* version in our study.

All studies (Ward, 1990; Ryan & Ward, 1999; Wymer, Rayls, & Wagner, 2003; Brooks & Weaver, 2006; Schoop, Herman, Johnstone, Callahan, & Roudebush, 2001; Axelrod, Ryan & Ward, 2001; Pilgrim, Meyres, Bayless & Whetstone, 1999; Kulas & Axelrod, 2002; Girard, Axelrod, & Wilkins, 2010) we have found on the validation of seven-subtest WAIS-III short-form, only focus on US standardization sample or on a clinical sample alone; none had a clinical group in one hand and a matched healthy group in the other hand to compare. As we have the two groups, we would like to highlight here, that our results showed that the psychometric properties of these Short Form versions are clearly different among the two studied groups, and this finding suggests that the results obtained with healthy controls might have limited generalizability to clinical samples.

In sum, long ago, Silverstein (1985) pointed out that there should be three criteria to judge the usefulness of a short form: (1) correlation between a short form and the full form should be highly significant, (2) estimated IQ should not differ significantly from the full form IQ and (3) the percentage of disagreement between a short form and the full form should not be so high as to negate the usefulness of the short form. The same author concludes its' review on WAIS-R short forms saying "the first criterion is virtually certain to be met, it makes little difference whether the second is met or failed, and the third is virtually certain to be failed" (p.679). A good part of our results are in agreement with this conclusion, even so we believe the short form can have an important usefulness with the refractory epilepsy patients. We support the idea that pre-surgical assessment should always be done with the WAIS-III full form, and every follow up year, the patient would be assessed by the short form. If specific additional information is desired in the post-surgical assessment, the full form could always be completed.

Sample size and the variability of some clinical variables among the epileptic group (e.g., age at seizure onset, duration of the epilepsy, location and lateralization of the epileptic trigger) can be noted as limitations of our study. Future studies may also consider having other short-form versions (e.g., Staz-Mogel or Index based Short Forms) and/or having three separate groups to compare: pre-surgical refractory epileptics, post-surgical refractory epileptics and healthy controls. However, overall this study has already

important implications on both clinical and research utilization of the WAIS-III's short forms.

CONCLUSION

This study supports the use of abbreviated versions when conducting epilepsy follow-up evaluations, but more important than praising the benefits of the time saving, this study revealed that a short-form validated for a healthy sample does not have the same accuracy properties when used with a clinical sample, therefore more psychometric work is needed to assure good short-form versions for different clinical samples.

Appendix 1. Frequency of accuracy of the discrepancy between real and estimated IQs

	≤-13	-12	-11	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	>13
Controls (n=30)																											
VIQ weighted									1	3	2	4	7	3	2	2	2	3				1					
VIQ prorated						1		2		1	2	3	4	7	3	4	1	1				1					
PIQ weighted BD					1	1	2		1	3	1	1	2	3	2	4	1	2	1			2		1		1	1
PIQ weighted MR		1		1		2	2	1	1		1	2	2	3	3	3	2	3					1	1	1			
PIQ prorated BD		2	1				1	4		1	1	1	2	2	2	3	3	1		1	1	2					2	
PIQ prorated MR		1		1		2		2	1	3		3	2	5	2	1	1	1	1	1	1		1	1				
FSIQ weighted BD								1		4	3	2	2	5	1	3	1	5	2	1								
FSIQ weighted MR									2	2	2	4	3	6	3	1	4	2		1								
FSIQ prorated BD						1			3	2	3	1	1	7	2	3	3	1	1	1	1							
FSIQ prorated MR	1					1		1	2	1		6	5	3	2	2	3	1	1	1								
Epilepsy (n=30)																											
VIQ weighted								1		2	1		3	3	6	2	1	2	4		2	1			1		1
VIQ prorated						1		2		1	2	3	4	7	3	4	1	1				1						
PIQ weighted BD					1			1	5	1	3	3	2	4	2	1	1	2			2	1					1	
PIQ weighted MR		1		1	1		3		2		3	3	1	3	3	3	1	1			1	1				1	1	
PIQ prorated BD		2	1				1	4		1	1	1	2	2	2	3	3	1		1	1	2					2	
PIQ prorated MR		1		1		2		2	1	3		3	2	5	2	1	1	1	1	1	1		1	1				
FSIQ weighted BD									1	1	1	1	3	9	3	2	3	1	1	2		2						
FSIQ weighted MR				1					1		2		3	5	4	4	4	2		2		1			1			
FSIQ prorated BD						1			3	2	3	1	1	7	2	3	3	1	1	1	1							
FSIQ prorated MR	1					1		1	2	1		6	5	3	2	2	3	1	1	1								

Appendix 2. Frequency of accuracy according to Wechsler (2008) classification

	VIQ					PIQ					FSIQ				
	-2	-1	0	1	2	-2	-1	0	1	2	-2	-1	0	1	2
Controls (n=30)															
Weighted BD		4	24	2			5	20	4	1		1	26	3	
Weighted MR		4	24	2			7	19	4			3	24	3	
Prorated BD		3	27				7	17	5	1		3	25	2	
Prorated MR		3	27				9	19	2		1	6	21	2	
Epilepsy (n=30)															
Weighted BD		4	19	7			5	22	2	1		1	23	6	
Weighted MR		4	19	7			6	22	1	1		1	22	7	
Prorated BD		4	17	9			5	22	3			1	22	7	
Prorated MR		4	17	9			4	24	2			1	22	7	

FINAL DISCUSSION

DISCUSSION

Before making the final conclusions, we shall remember the goals that guided this work. The original goal of was to validate the WAIS-III for Portuguese neurological patients, but the absence of positive results made us raise new questions and develop new goals. Although each chapter had already stated its specific goal(s), we could summarize the underlying questions quoting the list presented in the introduction of this thesis:

1. "Which clinical samples have been studied and how? (Study 1)
2. Is there a specific profile for brain tumor patients? (Study 2)
3. Which variables are responsible for this absence of profile(s)? (Study 3)
4. Could standardized discrepancies discriminate left from right brain lesions? (Study 4)
5. What holds unchanged after brain injury? (Study 5)
6. A short-form could be of use? (Studies 6 and 7)"

We have started our research as others researchers do, by selecting clinical samples according to disease etiologies. Our literature review (Study 1) showed us that WAIS-III, a traditional clinical and vocational test, eager to become a neuropsychological test. Most of the papers published about WAIS-III are published in Neuropsychological journals, and the most popular neurological samples are the Traumatic Brain Injury (TBI) followed by the mixed neuropsychiatric. TBI patients are expected to have a low Processing Speed Index (PSI), but unfortunately, this profile is no exclusive to TBI or to brain injury.

By the time we ended the literature review, we had also ended the data collection for primary brain tumor patients (Study 2), and we had already started the epilepsy and cerebrovascular (i.e., stroke and subarachnoid hemorraghe) patients' assessment. The results did not reveal a specific profile for brain tumor patients, though there were many significant differences between patient and control groups. We raised then the question that it all might be a bias created by the heterogeineity of brain lesion locations, but we could not test this question directly, once we did not have enough patients with the same brain lesion location. So we decided (1) to search for possible predictors of brain lesion (mixed sample study) and (2) to compare lateralized brain lesions (i.e., right *versus* left hemisphere lesions).

We had 81 mixed neurological patients and matched control data (study 3), we ran the multiple regression and ROC curve analysis. We found that although there were many significant differences between patients and controls, these differences have no clinical

usefulness, because both groups had performances that should be labeled as "normal" according to the test manual. Despite the recurrent failure to find a neuropsychological profile or a score that would discriminate brain lesion patients from normal controls, the results had showed that brain lesion (specifically, its presence, the age of onset and the years of survival) and literacy influences WAIS-III composite measures performance (i.e., IQs and Indexes).

Repeated comparisons for different subgroups and for different scores led us finally to a positive result (Study 5). Vocabulary consistently appeared as a measure for which both groups (i.e., clinical and control) had similar performance. Our results corroborated then the old idea that Vocabulary can be used as a good premorbid intelligence measure.

The lateralized lesions (Study 4) results led us again to negative results. No clinical usefull thumb rule was confirmed. However undesirable, these results were not unexpected; many studies pointed the same way for WAIS, WAIS-R and WAIS-III.

Last but not the least; we tried to validate a short-form (SF) version for the Portuguese WAIS-III (Studies 6 and 7). We explored the data for the whole mixed sample, and later we detailed this study for the refractory epilepsy group. The reason why we were interested in this specific group was that the long lists of psychological tests they do before surgery always include the WAIS-III. Once we had control group data, we compared the clinical group with the control group results; and as far as we are aware, this comparison is the first time done. This study encouraged the SF use post-surgically, but not pre-sirurgically; but above all, this study found psychometric differences between epileptic and control SF versions.

CONCLUSIONS

In short, despite the small sample size, with a mixed of neurological diseases and a lack of homogeinity in brain lesion locations, the results clearly reveal that WAIS-III is influenced by brain lesion and by literacy. How literacy and brain lesion influence WAIS-III performance remained as an unsolved questions though. Although the effects found are not large enough to be of use in clinical decision-making, readers should understand that absence of evidence does not equal evidence of absence.

As said before, results were disappointing and discouraging to the initial goal. We found no thumb rule or a profile that would help a clinician to do a good brain lesion screening or a better diagnosis with the full form WAIS-III. However, when we left the full form WAIS-III analysis apart, we started finding positive results. Vocabulary and short-

forms led us to promising results, both as estimated measures of intelligence. Vocabulary has showed to be a good estimate of premorbid verbal intelligence for a mixed neurologic sample and Ward seven-subtest short-form weighted formula has showed to be an acceptable estimation of actual intelligence (VIQ, PIQ and FSIQ) for a refractory epilepsy sample, and to mixed neurologic sample as well. In future studies, we may follow this clue and analyse patients performance in subtests or groups of subtests, like for example Digit Span, Matrix Reasoning, the three tests of Working Memory Index or the two test of Processing Speed Index; once some of these subtests are frequently used in neuropsychological assessment.

A final note to what stands out from our results. We strongly suggest that from now on, clinical and research studies with WAIS-III and neurologic patients should be tailored to have brain lesion location as the prime variable of the sample selection criteria. In our opinion, the sample selection by disease was the major limitation of this whole work, and maybe also responsible by the bias of many other studies, that fail to find acquire brain lesion on WAIS-III.

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ANEXOS

Anexo 1 = Study 1

Gonçalves, M.A., Simões, M.R., & Castro-Caldas, A. (2015). A systematic Review on WAIS-III research with a special focus on clinical studies. *Revista E-Psi, 5*(2), 51-85.

Anexo 2 = Study 2

Gonçalves, M.A, Simões, M.R. & Castro-Caldas, A. (2017). Interpreting WAIS-III Performance After Primary Brain Tumor Surgery. *Applied Neuropsychology: Adult, 24*(1), 42-49. doi: 10.1080/23279095.2015.1084508 (Published online 04 Mar 2016)

Anexo 3 = Study 3

Gonçalves, M.A., Moura, O., Castro-Caldas, A. & Simões, M.R. (published online 06 Jul 2016). Searching for a neurologic injury's Wechsler Adult Intelligence Scale-Third Edition profile, *Applied Neuropsychology: Adult*. doi:10.1080/23279095.2016.1199429

A systematic review on WAIS-III's research with a special focus on clinical studies

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Abstract

This systematic review was performed to explore (1) the main goal of the publications, (2) the inclusion criteria used for the most studied neurological samples, and (3) the main conclusions of the clinical/neurological/psychiatric studies which used the core/whole Wechsler Adult Intelligence Scale third edition (WAIS-III). EBSCO Host database was searched three times (2011, 2013 and 2014) using the keyword "WAIS-III" and the only limiters applied were "full text" and "scholarly (peer reviewed) journals". A total of 226 articles were identified. We classified 23 articles as no WAIS-III focus nor data, 28 as focused on other tests but with WAIS-III data, 28 as theoretical articles, 13 as articles on WAIS-III short-forms, 46 as articles with the technical manual samples, and 88 as articles with various kinds of samples. At the end, we came to the conclusions that (a) most of the articles published on this systematic review have neuropsychological issues as the main target, (b) most TBI samples focus on moderate severity, and in 18 out of 20 articles with the so called "mixed neuropsychiatric samples", there is no selection of brain injury samples according to injury localization, finally (c) it was not found an exclusive profile specific to brain injury.

Keywords

WAIS-III, brain injury, systematic review.

Introduction

Although Wechsler Adult Intelligence Scale – Fourth Edition (WAIS-IV) is already available in several non-English speaking countries (namely, France, Germany, Spain, Sweden, Danmark, Norway, Netherlands, India and Chile), many others countries (where Portugal is included) still use the WAIS-III, because they don't have the WAIS-IV standardization for their countries and/or because there is the clinical information we have now about WAIS-III make it a better clinical instrument than the WAIS-IV.

The Wechsler Adult Intelligence Scale – Third Edition (WAIS-III) was standardized in the United States of America (1997, *N*=2450), and extended for Australia (1997, *N*=297) and for the United Kingdom (1999, *N*=332). It was also standardized in Spain (1999, *N*=1369), France (2000, *N*=1104), Canada (2001, *N*=1100), China (2002, *N*=888), Mexico (2003, *N*=970), Finland (2005, *N*=446), Germany, Austria and Switzerland (German version, 2006, *N*=1181), and Portugal (2008, *N*=1181). Sweden (2003) and Denmark (2005) only translated the battery. South Africa (2010, *N*=84) published the preliminary studies on the standardization of the WAIS-III.

In 2008, the Portuguese technical manual included the results of the US clinical trial field samples and three national clinical small samples: temporal lobe epilepsy, schizophrenia and depressive states. Although the manual showed the results of the clinical US samples, we decided to look for more. Thus, the main goal of this research was to explore what kind of samples is being studied with the WAIS-III, knowing ahead that we had a special interest on the neurological samples.

In detail, this systematic review was performed to explore (1) the main goal of the publications, (2) the criteria used to select subjects for clinical/neurological studies, and (3) the main conclusions of the clinical/neurological studies which used the core or the whole battery.

Methods

EBSCO Host database (including PsychARTICLES, PsychINFO, Academic Search Complete, Education Source, and Psychology and Behavior Science Collection) was searched using the keyword "WAIS-III" and the limiters applied were "full text" and "Scholarly (peer reviewed) journals". The search took place in 2011-06-08, 2013-01-29 and 2014-01-14, always using the same search strategy: no language or publication date limiters were applied. Based on this process, 226 articles written in English and in Spanish, dated between 1998 and 2013, were identified.

Results and Discussion

(1) Classifying the publications according to main target and to main goal

As shown in Table 1, the three journals that published more articles on WAIS-III were journals focused on Neuropsychology. Table 1, also shows that the years with more publications are almost a decade after the US publication of the battery (1997), the top publication years vary from 2005 to 2010. Analyzing the journals that published more articles at Table 1, it seems that this battery, initially made for intelligence and intellectual disabilities assessment, apparently became a neuropsychological assessment standard.

Table 1. Journals that published more than 4 articles about WAIS-III, according to the year of publication.

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	**TOTAL**
The Clinical Neuropsychologist	1	1	4	2	4	4	5	3	3	2	3	4					**36**
Journal Clinical Experimental Neuropsychology			1			1	6	4	4	4	2		3				**25**
Applied Neuropsychology		1	1	1	1		2			4	4	7		2	1		**24**
Psychological Assessment		2	5	1	1	1	3		2	1				1			**17**
Intelligence				1	2	1			4	1		1	1				**11**
International Journal of Neuroscience		1	1	1	2		1	1				2					**9**
Journal of Clinical Psychology			1	1		2		1	1	1							**7**
… others with 4 or less articles	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	**97**
	1	**6**	**15**	**12**	**14**	**13**	**20**	**16**	**22**	**25**	**21**	**20**	**18**	**8**	**10**	**5**	**226**

Next, the reading and rating each item in accordance with its primary objective allowed a finding of 23 articles with word WAIS-III mentioned in the article but with no empirical WAIS-III data, 28 theoretical and/or no sample articles, 13 articles about the short-forms, 46 articles with standardization and/or technical manual samples, 28 articles focused on other tests (e.g., validation of other tests/tasks), and 88 articles with various kinds of samples and empirical data.

From the 23 articles somehow had the word WAIS-III on the text, that made them selected by the database, but the article didn't give any WAIS-III data, 10 focused on other WAIS versions or other Wechsler Scales (Crum, 2000; McPherson et al., 2000; Ryan et al., 2000; McCarthy et al., 2003; Saklofske et al., 2003; Hawkins & Tulsky, 2004; Tulsky, 2004; Lucas et al., 2005; Ryan et al., 2005; Herreras, 2010), 10 focused on other tests (Tishler et al., 2006; Williams & Donovick, 2008; Velassaris et al., 2009; Rabin et al., 2008; García-Molina et

al., 2010; Herreras, 2010; Vilaseca et al., 2010, Juncos et al., 2011; Theodore et al., 2012; Tseng et al., 2013), and finally 3 papers had nothing to do with Wechsler Scales nor related tests (Roid et al., 2005; Karson, 2004; Berry, 2008).

The 28 theoretical articles and/or articles with no sample could be subdivided in groups. Three articles were books reviews (Gregory, 2001; Donders, 2004; Larabee, 2004). Some were focused on the revision of the test and corrected norms (Nell, 1999; Okasaki & Sue, 2000; Tulsky & Ledbetter, 2000; Holdnack et al., 2004; Walker et al., 2009; Shuttleworth-Edwards, 2012), Flynn effect (Russell, 2007; Flynn, 2009), and index scores (Longman, 2004, 2005). Eight articles were focused on intellectual disabilities (Charter, 2003; Frumkin, 2006; Crawford et al., 2007; Whitaker, 2008; Suen & Greenspan, 2009a, 2009b; Escobedo & Hollingworth, 2009; Brooks et al., 2009). The rest of the articles focused on neuropsychological assessment (Herrera, 2008; Crawford & Garthwaite, 2009), short-form (Crawford et al., 2008), malingering (Mittenberg et al., 2002), specific subtests (Shuttleworth-Edwards, 2002; van Ommem, 2005), and gender effect (Molenaar et al., 2009).

There were 13 articles that focused on different ways of short-forms for different kinds of population (Pilgrim et al., 1999; Ryan et al., 1999; Ryan & Ward, 1999; Axelrod & Ryan, 2000; Schopp et al., 2001; Donders & Axelrod, 2002; Kulas & Axelrod, 2002; Clara & Huynh, 2003; Alley et al., 2007; Christensen et al., 2007; Lange et al., 2007; Dura et al., 2010). Among these articles there were several forms to abbreviate the WAIS-III: the most common way was to reduce the number of subtests (we found versions with 9, 7, 4 and 2 subtests), the other way was to reduce the number of items per subtest (we found at least three ways to select items). The only study that compared these two ways to abbreviate the WAIS-III (Kulas & Axelrod, 2002) gave the primacy to the reduced subtest form (SF-7) over the reduced-item form (Staz-Mogel SF).

There were 46 articles based on the standardization or clinical samples described in the technical manual. Out of these 46 studies, we found five that concerned the clinical field trial samples, all with English speaking samples (Hawkins, 1998; Wilde et al., 2004; Schoenberg et al., 2003; Schoenberg et al., 2006; Lange & Chelune, 2007). In fact, only 8 out of these 46 papers were made with non-english speaking samples (Gregoire, 2001; Colom et al., 2002; Juan-Espinosa et al., 2002; Dolan et al., 2006; Renteria et al., 2008; Grieve & van Eeden, 2010; Roivainen, 2010; Golay & Lecerf, 2011).

The remaining of these 46 studies used samples with English-speaking samples from United States of America, Canada, Australia or United Kingdom and were focused on sampling or updating norms (Bowden et al., 2003; Wycherley et al., 2005), demographic variables effects (Kaufman, 2000, 2001; Dori & Chelune, 2004; Lange, Chelune et al., 2006; Saklosfke et al., 2008), factor analysis (Caruso & Cliff, 1999; Saklosfke et al., 2000; Ward et al., 2000; Tulsky & Price, 2003; Taub et al., 2004; Bowden et al., 2006; Bowden et al., 2007;

Lange, 2007), *g* and General Ability Index (Tulsky et al., 2001; Lange et al., 2005; Saklosfke et al., 2005; Gignac, 2006a; 2006b; Kane & Krenzer, 2006; Lange et al., 2006; Lange, Chelune, & Tulsky, 2006), Oklahoma Premorbid Intelligence Estimate, OPIE-3 (Schoenberg et al., 2002; Schoenberg et al., 2004; Schoenberg et al., 2005), focused only on some subtests as Letter Number Sequencing (Tulsky & Zhu, 2000) or Digit Symbol (Joy et al., 2003; Ryan, Kreiner, & Tree, 2008), and finally focused on other theoretical issues (Tulsky et al., 2000; Zhu & Tulsky, 2000; Reddon et al., 2004; Allen & Barchard, 2009).

There were 28 articles focused on other tests or tasks but showing WAIS-III data, these papers could be divided in two: 18 that used the core or the whole battery (Martin et al., 2000; Bell et al., 2001; Devaraju-Backhaus et al., 2001; Lassiter et al., 2001; Titus et al., 2002; Loring et al., 2002; Mathias et al., 2007; Barker-Collo et al., 2008; Ford et al., 2008; Forn et al., 2008; Green et al., 2008; O'Hara et al., 2008; Wilbur et al., 2008; Cioe et al., 2010; Misdraji & Gass, 2010; Barker-Collo et al., 2011; Olivar-Parra et al., 2011; Wieland et al., 2012) *versus* 10 that used only some subtests (Carey et al., 2004; Fisher & Rose, 2005; Kilgore et al., 2005; O'Hora et al., 2005; Scott et al., 2006; Zook et al., 2006; Esperanza, 2007; Barreyro et al., 2009; Haatveit et al., 2010; Cabrera et al., 2011).

Finally, 88 articles had various kinds of samples. We decided to divide them again in two groups: those which used the core or the whole battery (n=47) and those which used only some subtests (n=41), as summarized in Table 2.

Table 2. Articles using the whole WAIS-III or some subtests with various kinds of samples.

	The whole WAIS-III was used	**Only some subtests were used**
Neurological samples	Martin et al. (2002) – Epilepsy Lange & Chelune (2006) – Alzheimer's Disease (AD) Moyle et al. (2007) – Phenilketonuria Ryan et al. (2009) – lateralized lesion Murayama et al. (2010) – Mild Cognitive Impairment Arreguín-González et al. (2011) – Cerebellar tumors Li et al. (2012) – AD and Mild Cognitive Impairment **Only Traumatic Brain Injury (TBI) samples:** Fisher et al. (2000) Axelrod et al. (2001) Axelrod et al. (2002) Van der Heidjen & Donders (2003) Langeluddecke & Lucas (2003) Langeluddecke & Lucas (2004) Strong et al. (2005) Greve et al. (2008) Blake et al. (2009) Walker et al. (2010)	Dugbartey et al. (1999) – Matrix Reasoning Bowler et al. (2001) – PSI+WMI subtests Earnst et al. (2001) – WMI subtests Wilde & Strauss (2002) – Digit Span Costello & Connolly (2005) – Picture Arrangement Stubberud et al. (2007) – Letter Number Sequencing Tranel et al. (2008) – Matrix Reasoning Dean et al. (2009) – Vocabulary and Digit Span Fucetola et al. (2009) – Block Design + Matrix Reasoning + Picture Arrangement Karzmark (2009) – Arithmetic Introzzi et al. (2010) – Matrix Reasoning Blanco-Rojas et al. (2013) – Digit Span **Only TBI samples:** Kennedy et al. (2003) – PSI+WMI subtests Noe et al. (2010) – WMI subtests

Psychiatric and neuropsychiatric samples	Ryan et al. (2002) – mixed sample Basso et al. (2002) – mixed sample Miller et al. (2004) – mixed sample Gorlyn et al. (2006) – Major Depression Iverson et al. (2006) – mixed sample Ryan et al. (2006) – mixed sample Ryan et al. (2007) – Substance Abuse Disorders Yao et al. (2007) – Schizophrenia Glass et al. (2009) – mixed sample Lin et al. (2010) – substance abuse Lin et al. (2012) – Schizophrenia Shan et al. (2013) – schizophrenia	Kreiner & Ryan (2001) – Digit Symbol Coding Zakzanis et al. (2003) – Vocabulary O'Bryan & O'Jile (2004) – Vocabulary Ditmann et al. (2007) – Letter Number Sequencing Glass et al. (2007) – Digit Symbol Tokley & Kemps (2007) – Object Assembly Pollice et al. (2010) – Digit Span Bossman et al. (2012) – Digit Span Bouso et al. (2012) – Letter Number Sequencing
Educational samples	Jones et al. (2006) – Low IQ sample Bigler et al. (2007) – Autism Fitzgerald et al. (2007) – Learning Disabilities Graue et al. (2007) – Mental Retardation Hayes et al. (2007) – Intellectual disability in prison Spinks et al. (2007) – School achievement Wierzbicki et al. (2007) – Learning and Attention Spek et al. (2008) – Asperger Syndrome Whitaker & Wood (2008) – Learning Disability Tirri et al. (2009) – Mathematically Gifted Students Copet et al. (2010) – Prader-Willi syndrome Gordon et al. (2010) – Special education students Nunes et al. (2013) – Williams Syndrome	Stearns et al. (2004) – WMI subtests Cheung et al. (2012) – Vocabulary, Similarities, Picture Completion and Block Design
Research samples (i.e., volunteers with no clinical diagnosis and/or students)	Abad et al. (2003) – University students Shuttleworth-Edwards et al. (2004) – South Africa Van der Sluis et al. (2006) – gender groups Greenaway et al. (2009) – MOANS Davis et al. (2011) – university students	Jung et al. (2000) – no Comprehension, Object Assembly and Picture Arrangement Mix & Crews (2002) – Block Design + Digit Symbol Lemay et al. (2004) – Letter Number Sequencing Shuttleworth-Edwards et al. (2004b) – Digit Symbol Hopko et al. (2005) – 5 performance subtests Cannon et al. (2006) – WMI+PSI subtests Etherthon et al. (2006) – PSI subtests Schwarz et al. (2006) – Digit Span + Vocabulary + Digit Symbol Coding + Symbol Search Cottone et al. (2007) – Comprehension + Similarities Ryan & Tree (2007) – 5 performance subtests Rozencwajg & Bertoux (2008) – Similarities Ryan et al. (2008) – supplementary and optional subtests Cannon et al. (2009) – WMI+PSI subtests Hill et al. (2010) – WMI subtests Davis & Pierson (2012) – Digit Symbol Coding Holtzer et al. (2012) – Vocabulary + Digit Symbol

Note: WMI = Working Memory Index, PSI = Processing Speed Index.

In sum, from the big pool of 226 papers on WAIS-III, the two most popular focus were studies with various kinds of samples on WAIS-III (n=88, 39%) and technical/psychometric studies made with the standardization samples (n=46, 20%). We were especially interested in these 88 "sample" studies, and we were surprised that only 15 papers included educational samples; against the 21 university and/or community samples, the 21 psychiatric or neuropsychiatric samples and the 31 neurological samples. We also noticed that slightly more than half of these 88 papers used the whole or the core battery (n=47) and the remaining used only one or a few subtests (n=41). We think this reflects the actual clinical use of the WAIS-III, as we all know that there are several environments where only a few subtests are used.

Last but not the least, looking in some detail to the last column of Table 2, we find out that the most popular subtests studied in these papers seemed to be Processing Speed Index's subtests (Digit Symbol Coding and Symbol Search), Working Memory Index's subtests (Digit Span, Arithmetic and LNS) and Matrix Reasoning (new subtest in this battery). Once again, these issues are very important in the neuropsychological assessment, once they enable levels of analysis focused on more specific neurocognitive functions.

(2) Criteria used for the selection of neurological samples

Next, we wanted to know the criteria used to select the more frequently studied neurological samples. It didn't matter if the study was based (1) on the core/whole WAIS-III, (2) on some subtests from the battery, (3) on WAIS-III short-forms or (4) on the validation/study of other tests. So we went back to the 226 articles and we selected all that had Traumatic Brain Injury (TBI) samples (Table 3) and "mixed neurological" samples (Table 4).

As shown in Table 3, there were 19 articles with TBI samples. A large number of articles had mild TBI subsample, but most the articles focus on moderate, moderate-severe or severe TBI. Near half of the articles didn't have a control group without TBI, 5 articles have a subsample of the standardization sample, and 4 articles had control samples with other clinical etiologies. Although most of the articles described the sample in detail (e.g., loss of consciousness, post-traumatic amnesia, time elapsed since injury), there were still 6 articles that didn't categorize their samples in severity of the TBI.

Table 3. TBI samples: frequency of different severities by samples.

		MTBI	M-MoTBI	MoTBI	Mo-STBI	STBI	ESTBI	Total TBI	Controls with no TBI
1	Fisher et al. (2000)	23			22			**45**	**45 matched from the standardization sample**
	Axelrod et al. (2001)		46					**46**	**n.r.**
	Axelrod et al. (2002)		51					**51**	**n.r.**
	Van der Heidjen & Donders (2003)	78			88			**166**	**n.r.**
	Langeluddecke & Lucas (2003)			35		74	41	**150**	**50 matched from the standardization sample**
	Langeluddecke & Lucas (2004)			35		74	41	**150**	**50 matched from the standardization sample**
	Miller et al. (2004)	15		3		10		**27**	**30 alcohol abuse + 43 polysubstance abuse**
	Strong et al. (2005)	53			47			**100**	**100 matched from the standardization sample**
	Greve et al. (2008)	127			84			**211**	**93 other neurological diagnosis**
	Blake et al. (2009)	18		8		31		**57**	**61 pseudoneurologic controls**
	Walker et al. (2010)							**196**	**n.r.**
2	Kennedy et al. (2003)	26		20		20		**66**	**n.r.**
	Noe et al. (2010)							**239**	**n.r.**
3	Schopp et al. (2001)							**118**	**n.r.**
	Donders & Axelrod (2002)	41			51			**100**	**100 matched from the standardization sample**
	Reid-Arndt et al. (2011)							**176**	**n.r.**
4	Martin & Donders (2000)	29			31			**53**	**n.r.**
	Green et al. (2008)							**24**	**n.r.**
	Wilbur et al. (2008)							**42**	**42 Learning Disabilities + 42 Emotional Diagnosis**

Note: n.r. = not reported; MTBI = Mild Traumatic Brain Injury (TBI); M-MoTBI = Mild to moderate TBI; MoTBI = Moderate TBI; Mo-STBI = Moderate to severe TBI; STBI = Severe TBI, and ESTBI = Extremely severe TBI. 1 = used 11, 13 or 14 subtests to study the TBI sample; 2 = used some subtests to study the TBI sample; 3 = short-form studies, and 4 = focus on other tests.

As it can be seen on Table 4, there were 20 articles that had mixed neurologic and/or neuropsychiatric samples. Only two of these articles described the subjects according to brain injury location: different locations of the prefrontal cortex but only matrix reasoning subtest (Tranel et al., 2008), and right versus left hemisphere injuries in the whole battery performance (Ryan et al., 2009). The remaining of the articles are mainly large series of accumulations of patients with various kinds of etiologies that vary a lot in age and gender.

Table 4. Mixed neurological/neuropsychiatric samples: Frequencies of the main etiologies and *M* and *SD* of demographic variables.

		N	**Neurologic diagnosis (*n*)**	**Psychiatric Diagnosis (*n*)**	**Unspecified clinical diagnosis or others (*n*)**	**Demographic variables by subsample**
1	Basso et al. (2002) – 3 and 6 months interval	51			51 patients screened for neurological and psychiatric disease	Age: 24.6 Education: 14.4 Gender: reported Ethnicity: reported
	Ryan et al. (2002) – Low versus high scatter groups	40 + 40	2/3 dementia	9/7 nonpsychotic 2/1 psychotic 21/20 substance abuse	5/3 brain injury 1/6 medical disorders	n= 40 / 40 Age: 50.18 SD 14.32 / 50.95 SD 12.92 Education: 13.12 SD 2.0 / 13.02 SD 2.12 Male: 100% / 100% Ethnicity: reported Handedness: reported
	Miller et al. (2004) – TBI versus Alcohol versus Polysubstance	100	27 head trauma	30 alcohol abuse 43 polysusbstance abuse		n= 27 / 30 / 43 Age: 33.44 SD 10.35 / 50.90 SD 11.37 / 42.40 SD 5.85 Education: 12.04 SD 1.7 / 11.93 SD 1.91 / 12.79 SD 1.54 Gender: 15M 12F / 29M 1F / 42M 1F Ethnicity: reported
	Iverson et al. (2006) – neuropsychiatric versus forensic groups	40 + 60		26 schizophrenia spectrum disorder 16 substance abuse 5 bipolar disorder	40 neuropsychiatric patients 13 undiagnosed forensic	n= 40 / 60 Age: 45.5 SD 11.4 / 36.3 SD 13.1 Education: 11.5 SD 2.9/ 10.2 SD 2.4 Male: 62,5%/85% Ethnicity: reported
	Ryan et al. (2006)	174	86 TBI 40 stroke 16 dementia 15 seizure disorders 5 tumor 2 meningitis 2 encephalitis 2 multiple sclerosis 2 encephalopathy			Age: 49.19 SD 15.33 Education: 12.57 SD2.78 Gender: 116M 58F Ethnicity: reported Control group: standardization sample (n=2450)
	Ryan et al. (2009) – left versus right hemisphere injury	36	20 vascular 14 TBI 1 Tumor 1 Tumor+TBI			n= 20 / 16 Age: 46.25 SD 17.42 / 47.86 SD 16.83 Education: 12.17 SD2.87 / 12.27 SD2.46

2	Dugbartey et al. (1999) – study 1	41	8 TBI 6 neurotoxin exposure 2 cerebral neoplasm 2 subarachnoid hemorrhage	5 unipolar depression 4 alcoholism	3 asymptomatic HIV 11 mixed diagnosis	Age: 38.2 SD 12.1 Education: 12.5 SD 2.81 Gender: 22M 19F Ethnicity: reported Handedness: reported
	Dugbartey et al. (1999) – study 2	14	2 seizure disorders 1 cerebrovascular 1 cerebral neoplasm	1 depression 1 schizophrenia	4 short-term memory loss 2 cardiac disease 1 hypertension 1 chronic renal disease	All immigrants Age: 55.56 SD 17.9 Education: 4.5 SD 4.3 Gender: 7M 7F Ethnicity reported
	Wilde & Strauss (2002)	44	35 TBI		9 various etiologies	Age: 37.1 SD 13.9 Education: 12.4 SD 2.0 Gender: 26M 18F
	Costello & Connolly (2005)	400			4x100 archival samples of two laboratories (no diagnosis)	Age: reported Gender: reported Education: n.r. Ethnicity: reported
	Tranel et al. (2008)	160	101 cerebrovascular 56 surgical resection* 3 herpes simplex encephalitis			Demographics reported for each of the four subsamples created.
	Karzmark (2009)	118	23 dementia 18 TBI 15 cerebrovascular 8 developmental 6 anoxia 4 tumor 7 others		25 psychiatric disorder 12 no diagnosis	Age: 47.2 SD 16.1 Education: 15.0 SD 2.9 Gender: 77M 41F Ethnicity: reported
	Bossman et al. (2012)	92	55.4% ischaemic stroke 16.3% haemorragic str. 7.6% Subarachnoid haemorrhage 5.4% post-anoxic 12% TBI 1.1% brain abscess 2.2% brain tumor			Age: 55.6 SD14.6 Education: 38.9% high school Gender: 48M 34F Consecutive inpatients
3	Pilgrim et al. (1999)	111	10.8% seizure disorder 9.9% TBI 9.9% vascular 3.6% subcortical dementia 1.8% hydrocephalus 1.8% encephalitis 2% brain tumor 9% Parkinson's disease		21.6% mental health 18.9% motor vehicle accident 4.5% learning disability 4.5%developmental 1.8% systemic lupus erythematosus 1.8% electrical injury 6.3% unspecified or multiple etiologies	Age: 40.49 SD 18.04 Education: 11.82 SD2.33 Gender: 65M 46F Ethnicity: reported Handedness: 85,6% right

	Axelrod & Ryan (2000)	278			278 patients referred for neuropsychological evaluation	Age: 51.8 SD 15.1 Education: 12.3 SD 2.3 Gender: 270M 8F Handedness: 90% right Ethnicity: reported
	Kulas & Axelrod (2002)	150	3% stroke 8% Alzheimer's disease 7% seizure disorder 3% multi-infart dementia 1% aneurism 10% TBI 1% Parkinson's disease 1% multiple sclerosis	19% substance abuse 14% mood disorder 11% schizophrenia 9% anxiety	6% free from neurologic or psychiatric condition	Age: 53.5 SD 14.2 Education: 12.2 SD 2.3 Gender: 95% male Handedness: 91% right Ethnicity: reported
	Lange et al. (2007)	100		26 schizophrenia spectrum disorder 16 substance abuse 5 bipolar disorder	40 neuropsychiatric patients 13 undiagnosed forensic	See above Iverson et al (2006)
4	Devaru-Backhaus et al. (2001)	85			22 psychiatric disorder 54 neurological disorder 9 no DSM-IV or neurological disorder	Age: 38.73 SD 16.54 Education: 13.07 SD 2.6 Gender: 40M 45F Handedness: 86,3%right Ethnicity: reported
	Fisher & Rose (2005)	32	18 TBI 2 cerebral hemorrhage 2 epilepsy 2 multiple sclerosis 1 cerebral palsy 1 cerebrovascular accident 1 Alzheimer's disease 1 encephalitis 1 hydrocephalus		3 unspecified neurologic problem	Age: 40 SD 13.38 Education: 12 SD 2.17 Gender: 18M 14F There were 2 other groups: 64 healthy volunteers subdivided in 32 controls and 32 simulators of memory impairment.
	Misdraji & Gass (2010)	192			192 consecutive neuropsychological referrals	Age: 59.3 SD 14.5 Education: 13.2 SD 2.2 Gender: 180M 12F

Notes: n.r. = not reported; 1 = used the core subtests; 2 = used some subtests; 3 = short-form studies, and 4 = focus on other tests. * 56 surgical resection = 23 benign tumor, 9 hematoma, 16 anterior temporal lobectomy for pharmacoresistent epilepsy, and 8 arteriovenous malformation.

(3) Is there a specific profile in acquired brain injury?

To answer this final question we focused on the 88 empirical articles with samples summarized in Table 2. From these articles, we first selected the 48 studies that had clinical samples (neurological, psychiatric or mixed neuropsychiatric). We then decided to pay special attention only to the studies that used 11, 13 or 14 subtests from the battery, and that gave us data about IQs, Indexes or subtests (middle column of Table 2). We called these studies, articles that "used the whole battery". We ended up with 29 clinical studies that used the whole/core battery and we sorted these studies by the samples: 6 mixed neurologic/neuropsychiatric (Table 5), 10 TBI (Table 6), 7 other neurologic etiologies (Table 7), and 6 psychiatric samples (Table 8).

We noticed that the six mixed neurological/neuropsychiatric samples that used the whole battery (Table 5), when characterized by etiology, were mainly addressing head trauma (i.e. TBI) or substance abuse disorders. These samples were all from North America, all reported a majority of Caucasian ethnicity, but only two studies reported handedness (Ryan et al., 2002; Glass et al., 2009). The samples were mainly of men with low-average or average IQ, mean aged from 40 to 50 years old (exception to the head trauma group described by Miller et al., 2004), and all had a mean education level of high school. Only one study had a control group of people with no clinical diagnosis; that group was the 2450 individuals from the US standardization sample (Ryan et al., 2006). Against our expectations, only one of these studies (Ryan et al., 2006) looked for a clinical profile and didn't find any difference in the inter-subtest scatter among brain injured patients compared to normal controls.

In what concerns the TBI samples (Table 6), 4 out of 10 articles selected concluded that the Processing Speed Index (PSI) is lower in all TBI samples with chronic and at least mild-to-moderate severity (Fisher et al., 2000; Axelrod et al., 2001; Axelrod et al., 2002; Langeluddecke et al., 2003). These results support the clinical trials (Hawkins, 1998), where the PSI was particularly sensitive to brain dysfunction; but the same results were obtained with Phenilketonuria patients (Moyle et al., 2007; see Table 7) and Depression samples as well (Gorlyn et al., 2006; see Table 8). So, although a low PSI is a good indicator of a TBI, it is also suggestive of other brain dysfunctions/diseases.

The other six articles with TBI samples were not looking for a clinical profile. One was trying to replicate the four-factor model (van der Heidjen & Donders, 2002), one discusses two methods for estimating premorbid intelligence (Langeluddecke & Lucas, 2004), two were focused on corrected norms (Strong et al., 2005; Blake et al., 2009), one focus on Australian cultural diversity (Walker et al., 2010) and, finally one was focused on malingering (Greve et al., 2008).

Table 5. Descriptive analysis (*M* and *SD*) and main conclusions from the mixed neurological/neuropsychiatric samples.

	Etiology	Age	Education	Gender	VIQ	PIQ	FSIQ	VCI	POI	WMI	PSI	Subtests	Main conclusions
Basso et al. (2002)	51 patients screened for neurological and psychiatric disease: - baseline	n.r.	n.r.	n.r.	111.0 (11.5)	105.4 (12.5)	109.4 (11.6)	111.5 (11.9)	106.1 (14.1)	106.9 (12.4)	109.3 (13.0)	n.r.	All IQs and indexes, except WMI, improved significantly from baseline to 3- or 6-months reevaluation
	- retest	n.r.	n.r.	n.r.	114.8 (11.5)	116.0 (14.4)	115.04 (12.1)	115.8 (12.3)	114.4 (14.1)	108.6 (13.1)	116.4 (14.5)	n.r.	
Ryan et al. (2002)	40 low scatter group*	50.18 (14.32)	13.12 (2.00)	40M	101.15 (10.78)	98.38 (10.56)	99.88 (10.47)	n.r.	n.r.	n.r.	n.r.	11 subtests reported	When differences in IQ are controlled, the intersubtest scatter does not predict memory performance
	40 high scatter group**	50.95 (12.92)	13.02 (2.12)	40M	100.38 (11.83)	99.18 (13.26)	99.78 (10.30)	n.r.	n.r.	n.r.	n.r.	11 subtests reported	
Miller et al. (2004)	30 alcohol abuse	50.90 (11,37)	11.93 (1.91)	29M 1F	93.70 (10.94)	92.17 (10.13)	92.60 (10.03)	n.r.	n.r.	n.r.	n.r.	Vocabulary + Digit Span	Vocabulary – Digit Span score has 99% overall accuracy detecting malingering
	43 polysubstance abuse	42.40 (5.85)	12.79 (1.54)	42M 1F	98.51 (14.11)	97.09 (14.17)	99.40 (14.73)	n.r.	n.r.	n.r.	n.r.	Vocabulary + Digit Span	
	27 head trauma	33.44 (10.35)	12.04 (1.70)	15M 12F	93.37 (11.44)	93.52 (8.17)	93.04 (9.11)	n.r.	n.r.	n.r.	n.r.	Vocabulary + Digit Span	

Iverson et al. (2006)	40 neuropsychiatric + 60 forensic psychiatric: - American norms	n.r.	n.r.	n.r.	84.9 (14.3)	81.4 (14.8)	82.0 (14.6)	86.9 (15.5)	86.1 (15.3)	82.5 (16.2)	76.6 (13.2)	11 subtests reported	Significantly lower scores on all IQs, Indices, and subtest scores will be calculated when using the Canadian versus the American norms
	- Canadian norms	n.r.	n.r.	n.r.	82.0 (12.8)	76.5 (14.9)	78.1 (13.0)	84.3 (13.4)	81.3 (14.6)	79.9 (14.2)	73.8 (14.3)	11 subtests reported	
Ryan et al. (2006)	174 mixed neurologic patients***	49.19 (15.33)	12.57 (2.78)	116M 58F	89.06 (16.36)	86.17 (17.12)	88.45 (17.78)	89.82 (16.54)	89.99 (17.26)	84.84 (16.34)	79.51 (13.45)	13 subtests reported	Inter-subtest scatter among brain-damaged patients is no greater than among normal persons
Glass et al. (2009)	82 polysubstance abuse + 53 alcohol abuse	47.16 (9.19)	12.55 (1.58)	135M 0F	n.r.	n.r.	92.10 (13.73)	94.39 (13.61)	93.51 (14.27)	92.57 (14.30)	86.46 (11.99)	n.r.	GAI and FSIQ were highly correlated

Note: n.r. = not reported; VIQ = Verbal IQ; PIQ = Performance IQ; FSIQ = Full Scale IQ; VCI = Verbal Comprehension Index; POI = Perceptual Organization Index; WMI = Working Memory Index; PSI = Processing Speed Index. *9 nonpsychotic psychiatric disorders; 2 psychotic psychiatric disorders; 5 neurological disorders involving brain; 1 medical disorder; 21 substance abuse disorders; 2 dementia. **7 nonpsychotic psychiatric disorders; 1 psychotic psychiatric disorders; 3 neurological disorders involving brain; 6 medical disorder; 20 substance abuse disorders; 3 dementia. ***86 TBI; 40 stroke; 16 dementia; 15 seizure disorders; 5 tumors; 2 meningitis; 2 encephalitis; 2 multiple sclerosis; 2 anoxia; 2 hydrocephalus; 1 each cardiac and hepatic encephalopathy.

Table 6. Descriptive analysis (*M* and *SD*) and main conclusions from the TBI samples.

	TBI severity	Age	Education	Gender	Time elapsed	VIQ	PIQ	FSIQ	VCI	POI	WMI	PSI	Subtests	Main Conclusions
Fisher et al. (2000)	45 controls from standardization sample	32.53 (9.93)	12.96 (1.94)	n.r.	n.a.	100.0 (13.8)	101.7 (14.6)	100.8 (14.0)	99.2 (14.6)	102.4 (14.3)	100.6 (16.4)	99.6 (14.0)	n.r.	No IQ or index score will help discriminate mild TBI patients from normal controls. IQ and index scores were lower for moderate-severe TBI, even when controlling for education level; PSI was particularly low
	23 mild TBI	35.73 (11.33)	12.87 (2.53)	12M 11F	431 days (367.9)	96.3 (12.7)	100.0 (13.8)	98.0 (13.1)	95.8 (16.0)	104.6 (15.4)	96.1 (11.2)	95.3 (12.2)	n.r.	
	22 moderate-severe TBI	26.9 (5.9)	13.32 (1.67)	14M 8F	n.r.	89.6 (12.4)	84.5 (13.8)	86.5 (10.9)	89.6 (12.7)	92.1 (15.0)	89.8 (13.1)	73.4 (10.7)	n.r.	
Axelrod et al. (2001)	46 at least mild-moderate TBI	33.5 (13.3)	12.6 (2.3)	32M 13F	4.9 months (5.8)	88.5 (14.7)	85.1 (16.0)	85.6 (15.4)	88.2 (15.0)	88.1 (16.0)	90.4 (11.9)	79.6 (11.7)	n.r.	PSI was more sensitive (but not specific) to brain injury than other WAIS-III composites
	22 controls from standardization sample	n.r.	n.r.	n.r.	n.a.	89.6 (12.4)	84.5 (13.8)	86.5 (10.9)	89.6 (12.7)	92.1 (15.0)	89.8 (13.1)	73.4 (10.7)	n.r.	
Axelrod et al. (2002)	51 at least mild-moderate TBI	33.9 (13.5)	12.5 (2.3)	35M 16F	4.2 months (5.0)	90.5 (15.5)	86.4 (15.8)	87.9 (15.8)	90.4 (16.0)	89.8 (16.1)	90.8 (12.7)	81.0 (1.9)	n.r.	PSI was significantly lower than other indexes. Tables of frequencies differences
van der Heidjen & Donders (2003)	78 mild TBI + 88 moderate-severe TBI	33.14 (14.84)	12.64 (1.93)	105M 61F	92.14 days (69.38)	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	A four-factor model, similar to the technical manual, provided the best fit to the clinical data

	50 controls from standardization sample	38.3 (20.8)	12.7 (2.9)	24M 26F	n.a.	104.9 (16.0)	104.08 (15.3)	105.4 (16.3)	105.7 (15.7)	104.7 (15.3)	102.8 (15.5)	102.4 (16.6)	13 subtests reported	Subtests scores are discussed.
	35 moderate TBI	35.6 (13.8)	11.9 (2.5)	24M 12F	32.1 months (19.7)	102.1 (14.7)	100.9 (14.4)	101.7 (14.4)	103.0 (15.5)	104.07 (15.4)	101.9 (14.4)	93.1 (12.6)	13 subtests reported	PSI scores were lower by an average of 9 points.
Langeluddecke & Lucas (2003)	74 severe-very severe TBI	31.5 (11.3)	11.6 (2.4)	53M 22F	34.1 months (24.6)	94.5 (14.6)	91.7 (13.6)	92.7 (14.3)	95.2 (15.0)	95.6 (14.4)	94.4 (14.1)	88.1 (12.9)	13 subtests reported	PSI scores were lower by an average of 14 points, and FSIQ an average approximately 9 points.
	41 extremely severe TBI	36.6 (13.2)	11.3 (2.6)	29M 15F	33.9 months (23.1)	89.7 (15.1)	86.4 (12.5)	87.3 (14.3)	90.5 (14.5)	91.2 (12.7)	90.1 (16.9)	80.1 (13.0)	13 subtests reported	PSI scores were lower by an average of 22 points, and FSIQ an average approximately 16 points.
Langeluddecke & Lucas (2004)	same as Langeluddecke & Lucas (2003)	see above	see above	see above	see above	see above	see above	see above	see above	see above	see above	see above	n.r.	Discusses two methods for estimating premorbid intelligence
Strong et al. (2005)	53 mild + 47 moderate-severe TBI	33.92 (15.43)	12.60 (2.08)	66M 34F	102.43 days (76.67)	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	Demographically corrected norms are not clearly better or worse than the conventional age-corrected norms
	100 controls from standardization sample	34.29 (15.94)	12.53 (2.181)	66M 34F	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	

Greve et al. (2008)	93 general clinical (other diagnosis)	57.0 (16.1)	14.1 (2.6)	48M 45F	n.r.	95.0 (15.5)	90.4 (14.8)	92.4 (14.7)	n.r.	n.r.	n.r.	n.r.	n.r.	VIQ accurately differentiated malingering from non-malingering patients regardless of injury severity PIQ was only accurate in mild TBI and did not add increment validity to the VIQ
	127 mild TBI + 84 moderate-severe TBI	38.3 (13.6)	12.1 (3.1)	151M 60F	22.1 months (26.0)	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	
	87 TBI not-malingering	n.r.	n.r.	n.r.	n.r.	95.8 (15.5)	94.3 (17.2)	94.8 (16.5)	n.r.	n.r.	n.r.	n.r.	n.r.	
	68 TBI indeterminate malingering	n.r.	n.r.	n.r.	n.r.	87.9 (14.1)	88.1 (14.6)	87.2 (14.6)	n.r.	n.r.	n.r.	n.r.	n.r.	
	56 TBI malingering	n.r.	n.r.	n.r.	n.r.	75.6 (12.6)	77.9 (13.7)	74.5 (13.4)	n.r.	n.r.	n.r.	n.r.	n.r.	
Blake et al. (2009)	18 mild + 8 moderate + 31 severe TBI	40.70 (16.90)	13.00 (1.94)	36M 21F	8.51 months (25.65)	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	11 subtests reported	The corrected norms are no more or less beneficial than traditional age-corrected norms for neurodiagnostic purposes
	61 controls (pseudoneurologic group)	45.46 (13.13)	13.23 (2.62)	17M 44F	16.92 months (18.57)	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	11 subtests reported	

Walker et al. (2010)	130 moderate-severe TBI - english-australian	30.7 (12.0)	11.0 (2.2)	98M 32F	28.2 weeks (21.8)	93.3 (13.8)	90.9 (13.7)	n.r.	92.9 (14.3)	94.3 (14.0)	93.9 (14.1)	85.6 (12.2)	11 subtests reported	The English-educated culturally and linguistically diverse group performed lower than the English-speaking background group on some verbal WAIS-III measures The non-English-educated diverse group performed lower than both groups on several WAIS-III measures
	33 moderate-severe TBI - "english country"	27.2 (10.6)	11.0 (1.8)	27M 6F	25.3 weeks (20.4)	87.2 (13.0)	88.3 (13.0)	n.r.	87.5 (12.7)	92.3 (13.3)	88.1 (15.2)	82.9 (12.3)	11 subtests reported	
	33 moderate-severe TBI - "non english country"	43.9 (13.1)	10.8 (3.2)	27M 6F	25.7 weeks (17.9)	n.r.	79.0 (11.2)	n.r.	n.r.	81.8 (11.7)	n.r.	78.9 (11.8)	11 subtests reported	

Note: n.r. = not reported; n.a. = not applicable; VIQ = Verbal IQ; PIQ = Performance IQ; FSIQ = Full Scale IQ; VCI = Verbal Comprehension Index; POI = Perceptual Organization Index; WMI = Working Memory Index; PSI = Processing Speed Index.

Table 7. Descriptive analysis (*M* and *SD*) and main conclusions from the other neurological samples.

	Etiology	Age	Education	Gender	VIQ	PIQ	FSIQ	VCI	POI	WMI	PSI	Subtests	Main Conclusions
Martin et al. (2002)	42 unoperated-on adult patients with complex partial seizures	34.8 (11.3)	13.2 (2.6)	13M 29F	86.6 (16.1)	86.4 (14.6)	85.5 (15.9)	87.0 (14.6)	88.0 (15.1)	89.1 (17.6)	n.r.	11 subtests reported	Individual subtests for the WAIS-III were less reliable than the Index scores but still within very acceptable reliability ranges
	42 same sample, mean 7-month retesting interval	same	same	same	86.4 (16.4)	89.5 (14.6)	86.9 (16.1)	87.6 (15.4)	90.8 (14.3)	87.6 (16.2)	n.r.	11 subtests reported	
Lange et al. (2006)	34 patients with Alzheimer's type dementia	73.0 (7.2)	14.5 (2.9)	19M 15F	n.r.	n.r.	n.r.	93.2 (12.1)	85.1 (12.4)	n.r.	n.r.	n.r.	GAI-memory discrepancy differentiate patients with DAT from healthy participants, however failed to provide unique interpretive information beyond that which is gained from memory indexes alone
	34 controls matched from the standardization sample	72.9 (7.1)	14.2 (2.7)	19M 15F	n.r.	n.r.	n.r.	109.8 (15.4)	105.7 (12.4)	n.r.	n.r.	n.r.	
Moyle et al. (2007)	12 Phenylketonuria (PKU) treated with a low-phenylalanine diet from birth	28.5 (3.3)	11.8 (0.5)	2M 10F	n.r.	n.r.	n.r.	105 (n.r.)	101 (n.r.)	103 (n.r.)	92 (n.r.)	n.r.	POI and PSI were significantly lower in the PKU group. Taken together with WMS-III and TMT scores, these results supported a profile of reduced information-processing speed
	12 controls (friends of PKU group)	29.2 (3.2)	12.2 (0.5)	Matched	n.r.	n.r.	n.r.	106 (n.r.)	115 (n.r.)	101 (n.r.)	106 (n.r.)	n.r.	

Ryan et al. (2009)	20 left brain lesion (mixed etiology)	46.25 (17.42)	12.17 (2.87)	n.r.	86.70 (17.78)	87.45 (15.65)	n.r.	87.10 (17.04)	94.25 (15.84)	n.r.	n.r.	n.r.	Neither VIQ-PIQ nor VCI-POI discrepancy scores were effective in identifying lateralized brain damage.
	16 right brain lesion (mixed etiology)	47.86 (16.83)	12.27 (2.46)	n.r.	92.56 (16.48)	82.56 (15.58)	n.r.	90.95 (14.50)	86.06 (15.26)	n.r.	n.r.	n.r.	
Murayama et al. (2010)	8 early Mild Cognitive Impairment (MCI)	70.5 (3.1)	14.6 (2.1)	5M 3F	127.1 (8.0)	120.3 (8.4)	126.5 (7.1)	121.1 (8.1)	n.r.	n.r.	n.r.	n.r.	The discrepancy between intelligence and memory scores combined with F-FDG PET findings would make it possible to diagnose early-stage amnestic MCI.
	10 MCI	68.8 (5.5)	13.8 (2.2)	3M 7F	113.9 (11.4)	105.8 (8.7)	111.4 (10.5)	107.6 (12.2)	n.r.	n.r.	n.r.	n.r.	
	6 controls	68.3 (4.7)	14.0 (1.8)	2M 4F	113.3 (10.2)	107.7 (9.5)	112.2 (10.5)	107.3 (7.6)	n.r.	n.r.	n.r.	n.r.	
Arreguín -González et al. (2011)	12 untreated cerebellar tumor	45 (1.3)	n.r.	8M 3F	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	A tumor in the cerebellum may cause substantially lower mean IQ.
Li et al. (2012)	30 patients = = 18 Alzheimer's Disease + +12 Mild Cognitive Impairment	73.80 (8.26)	n.r.	8M 22F	82.74 (18.60)	78.04 (19.12)	79.00 (19.85)	n.r.	n.r.	n.r.	n.r.	14 subtests reposted	Z-scores of VSRAD were revealed to have close relation with many neuropsychological tests, especially ADAS-cog and subtest Information

Note: n.r. = not reported; VIQ = Verbal IQ; PIQ = Performance IQ; FSIQ = Full Scale IQ; VCI = Verbal Comprehension Index; POI = Perceptual Organization Index; WMI = Working Memory Index, and PSI = Processing Speed Index and VSRAD = voxel-based specific regional analysis system for Alzheimer's disease.

Table 8. Descriptive analysis (*M* and *SD*) and main conclusions from the psychiatric samples

	Etiology	Age	Education	Gender	VIQ	PIQ	FSIQ	VCI	POI	WMI	PSI	subtests	main conclusions
Gorlyn et al. (2006)	41 non-patients controls	33.80 (11.9)	16.49 (2.5)	20M 21F	118.3 (18.0)	115.1 (18.4)	118.4 (17.9)	120.5 (17.3)	113.4 (17.1)	109.8 (17.3)	110.0 (13.8)	11 subtests reported	Results suggest general intellectual performance in depression is best characterized by deficits in processing speed.
	81 major depression + 40 bipolar disorders	38.40 (12.0)	15.86 (2.4)	50M 71F	114.3 (14.2)	108.4 (17.0)	112.9 (15.2)	117.1 (14.0)	109.5 (16.5)	106.8 (14.8)	101.9 (15.5)	11 subtests reported	
Ryan et al. (2007)	131 substance abuse disorders	47.16 (9.14)	12.59 (1.58)	132M 2F	n.r.	n.r.	92.37 (14.14)	n.r.	n.r.	n.r.	n.r.	n.r.	Case-by-case analyses demonstrated concordance rates of 99% for the IMI-GMI and IMI-DMI comparisons and 94% for the FSIQ-GMI and FSIQ-DMI contrasts
Yao et al. (2007)	114 schizophrenia	32.5 (10.2)	10.5 (2.9)	60M 54F	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	The results of the present study with two Chinese mainland samples provide further support for the WAIS-III Chinese version four factor structure.
	114 controls from standardization sample	32.8 (10.3)	10.6 (3.2)	53M 61F	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	
Lin et al. (2010)	34 methamphetamine-induced psychosis	28.7 (6.1)	10.4 (1.8)	28M 6F	84.3 (11.9)	81.9 (12.1)	82.3 (10.8)	85.5 (11.9)	84.7 (12.5)	85.4 (13.6)	78.5 (12.7)	13 subtests reported	Although methamphetamine-induced psychosis patients were younger, with shorter duration of substance misuse than alcoholic patients, their mentality had more severe deterioration.
	34 alcohol dependent	40.7 (7.3)	11.1 (2.8)	32M 2F	95.2 (11.3)	86.0 (13.8)	90.5 (12.0)	95.5 (11.0)	87.1 (14.5)	96.2 (13.1)	84.5 (15.0)	13 subtests reported	

Lin et al. (2012)	120 schizophrenia	37.96 (9.86)	13.08 (2.84)	58M 62F	94.53 (17.08)	90.61 (16.84)	92.52 (15.63)	n.r.	n.r.	92.10 (17.57)	n.r.	5 subtests reported	Mismatch negativity deficits were found in Han Chinese schizophrenia patients. The multivariate approach combining biomarkers from different modalities such as electrophysiology and neuropsychology had a better diagnostic utility.
	76 healthy controls	36.25 (1.12)	15.73 (3.52)	30M 46F	112.67 (16.22)	113.06 (16.56)	112.25 (18.88)	n.r.	n.r.	112.14 (15.30)	n.r.	5 subtests reported	
Shan et al. (2013)	106 schizophrenia	37.2 (10.0)	13.8 (2.7)	52M 54F	95.74 (16.76)	90.58 (18.05)	93.21 (16.15)	n.r.	n.r.	93.14 (17.66)	n.r.	5 subtests reported	The first diagnostic model for schizophrenia in subjects of Chinese ethnicity, using P50 sensory gating along with neuropsychological tests
	74 controls	36.2 (11.5)	15.3 (3.6)	31M 43F	113.0 (16.28)	113.5 (16.53)	114.1 (19.04)	n.r.	n.r.	112.5 (15.34)	n.r.	5 subtests reported	

Note: n.r. = not reported; VIQ = Verbal IQ; PIQ = Performance IQ; FSIQ = Full Scale IQ; VCI = Verbal Comprehension Index; POI = Perceptual Organization Index; WMI = Working Memory Index; PSI = Processing Speed Index; DMI = Delayed Memory Index, and GMI = General Memory Index.

Comparing the TBI samples (Table 6) with other mixed neuropsychiatric samples (Table 5), we noticed that TBI samples are a decade younger (TBI mean age is most of the times between 30 and 40); education level is apparently the same as other neurologic samples (high-school), but the disproportion of male versus female is higher in TBI samples. Although there were some studies in a post-acute phase for TBI samples (van der Heidjen & Donders, 2003; Strong et al., 2005; Walker et al., 2010), the majority of TBI studies focused on chronic patients. For the mixed neuropsychiatric samples, there is no report about the time elapsed since diagnosis/injury.

In sum, from the 29 "clinical samples" papers selected, only 9 had a goal equal or similar to looking for a clinical profile in the WAIS-III (Fisher et al., 2000; Axelrod et al., 2001; Axelrod et al., 2002; Langeluddecke et al., 2003; Gorlyn et al., 2006; Ryan et al., 2006; Ryan et al., 2009; Moyle et al., 2007; Arreguín-González et al., 2011). Further, based on these studies, the most robust conclusion we came to was that the PSI is sensitive to many clinical groups, including the Traumatic Brain Injury (TBI). Although the WAIS-III is sensitive to acquired brain injury, there is nothing exclusive to acquired brain injury or no such thing a specific neuropsychological profile for WAIS-III, identified in this systematic review.

Conclusions

Answering three main questions of this systematic review, the first finding was that the journals which published more articles on WAIS-III have neuropsychologists for main target. These numbers reflect the acknowledgment of the importance of the Wechsler Intelligence Scales in neuropsychological assessment and the growing hegemony of neuropsychological assessment in the evaluation practices.

It is worth noting that only 8 out of 46 (17%) of what we called "technical manual" papers focused on non-English speaking samples. We believe this percentage is very low, considering the worldwide importance of the WAIS.

From the total pool of articles the two most popular neurological samples were selected to analyze how these samples were recruited. There were 19 articles focused on TBI samples and 20 on mixed neuropsychiatric samples. Most of these studies had big samples (sample size varied from 24 up to 400). Around two thirds of the 19 TBI articles describe the participants in detail according to the severity of the injury. But, the so called "mixed neuropsychiatric samples" are most of the times a heterogeneous accumulation of various kinds of diseases. Moreover only 2 out of 20 "mixed clinical" articles in this review selected the participants according to the injury localization (Tranel et al., 2008; Ryan et al., 2009).

Finally, from the pool of 88 "sample" papers, all studies that used the whole battery and neurologic and/or psychiatric samples (n=29) were selected. The results of these studies lead to the conclusion that although the WAIS-III PSI is sensible to TBI and to other clinical

groups (e.g., depression), there is nothing specific to brain injury only, and it was not found such thing as an exclusive neuropsychological profile for the WAIS-III in this review.

The important effect of brain injury localization in the performance of multiples cognitive tests is widely recognized among neuropsychologists; however its potential effect on the WAIS-III performance is apparently neglected by the majority of the studies in this review. We believe that most papers fail to find a more specific profile in acquired brain injury samples, because they give primacy to the etiology over brain injury location. Therefore, we would like to suggest that authors should be strongly encouraged to organize their case material, taking in consideration lesion location.

We wouldn't like to finish without pointing out at least two major limitations of this study. We believe our biggest limitation is that we only used one database: EBSCO Host. We preferred it over PubMed, because we thought we would find a more general overview in psychological research. Although EBSCO Host includes many American Psychological Association (APA) databases, the PubMed could have been a better research tool, when clinical aspects are concerned. A second limitation is that we only read the papers "full text pdf" and sometimes other important research is not in open access. Albeit the open access papers from this database can give us a restricted access to the important WAIS-III research, this review introduced us to a new reality: WAIS-III is becoming more and more a neuropsychological instrument, and progressively less a counseling/vocational instrument, but there is still work to be done in what concerns the effect of different brain injury locations on the WAIS-III performance.

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Revisão sistemática sobre a WAIS-III com especial interesse nos estudos clínicos

Resumo

Nesta revisão sistemática, pretendeu-se explorar como tem sido estudada a Escala de Inteligência de Wechsler para Adultos 3ª versão (WAIS-III): (1) quais os principais temas de publicados, (2) quais os critérios de inclusão utilizados nos estudos com amostras neurológicas e (3) as principais conclusões dos estudos clínicos/neurológicos/psiquiátricos que utilizaram entre 11 e 14 subtestes da bateria. A pesquisa foi feita através da EBSCO-Host por três vezes (2011, 2013 e 2014), utilizando a palavra-chave "WAIS-III" e limitando a pesquisa a "full text" e "scholarly (peer reviewed) journals". Foram identificados 226 artigos: 23 dos quais foram classificados como não tendo o foco ou resultados centrados na WAIS-III, 28 artigos com foco noutro teste ou tarefa, mas utilizando a WAIS-III, 28 artigos teóricos, 13 artigos sobre formas abreviadas, 46 artigos com amostras de estandardização e 88 artigos com amostras de vários tipos. Como principais conclusões apontamos que (1) o maior número das artigos está publicado em revistas especializadas em neuropsicologia, (2) a maioria das amostras com traumatizados cranioencefálicos são de gravidade moderada-grave e nas amostras chamadas "mistas" não há seleção dos sujeitos respeitando ao local da lesão e finalmente (3) não foram encontrados perfis de resposta exclusivas para os doentes com lesão cerebral.

Palavras-chave

WAIS-III, lesão cerebral, revisão sistemática.

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Interpreting WAIS-III Performance After Primary Brain Tumor Surgery

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Interpreting WAIS-III Performance After Primary Brain Tumor Surgery

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ABSTRACT

The literature lacks information on the performance of patients with brain tumors on the Wechsler Intelligence Scales. This study aimed to explore the Wechsler Adult Intelligence Scale-Third Edition (WAIS-III) performance profile of 23 consecutive patients with brain tumors and 23 matched controls selected from the Portuguese WAIS-III standardization sample, using the technical manual steps recommended for score interpretation. The control group was demographically matched to the tumor group regarding gender, age, education, profession, and geographic region. The technical manual steps recommended for score interpretation were applied. Patients with brain tumors had significantly lower performances on the Performance IQ, Full-Scale IQ, Perceptual Organization Index, Working Memory Index, Processing Speed Index, Arithmetic, Object Assembly, and Picture Arrangement, though all scaled scores were within the normal range according to the manual tables. Only Vocabulary and Comprehension scatter scores were statistically different between groups. No strengths or weaknesses were found for either group. The mean discrepancy scores do not appear to have clinical value for this population. In conclusion, the study results did not reveal a specific profile for patients with brain tumors on the WAIS-III.

KEYWORDS

Brain tumor; intelligence; profile scores; review WAIS-III

Introduction

Little is known about the performance of patients with brain tumors on various versions of the Wechsler Intelligence Scales. Neither the American Wechsler Adult Intelligence Scale-Third Edition (WAIS-III) technical manual (Psychological Corporation, 1997) nor the Portuguese WAIS-III technical manual (Wechsler, 2008) include a validation study with patients with brain tumors. The most comprehensive reviews on the WAIS-III (Kaufman & Lichtenberger, 1999; Tulsky et al., 2003) do not mention any specific information about this clinical group. The same happens with the American version of the Wechsler Adult Intelligence Scale-Fourth Edition (WAIS-IV; Holdnack, Dorzdick, Weiss, & Iverson, 2013; Lichtenberger & Kaufman, 2013; Psychological Corporation, 2008).

In January 2014, Gonçalves, Simões, and Castro-Caldas (2014, 2015) ran a systematic review with the keyword "WAIS-III" in the EBSCOhost database and only two limiters: "full text" and "scholarly (peer reviewed) journals." Two hundred and twenty-six articles were identified. Out of these, only 1 article (Arreguin-Gonzalez et al., 2011) studied a whole sample with 11 patients with untreated cerebellar tumors. There were 7 articles with mixed samples of patients with brain tumors among patients with other etiologies. None of these studies evaluated patients with brain tumors in non-mixed-etiology sample. The majority of the 7 articles identified in this first search as having patients with brain tumors in their samples included less than 5% of patients with this etiology. Pilgrim, Meyers, Bayless, and Whetstone (1999) included 2 patients with tumors in a sample of 111 participants (2%). Bossman, Visser-Meily, Post, Lindeman, and Van Heugten (2012) included 2 patients with tumors in a sample of 92 participants (2.2%). Ryan, Tree, Norris, and Gontkosvsky (2006) included 5 patients with tumors in a sample of 174 participants (2.9%). Karzmark (2009) included 4 patients with tumors in a sample of 118 participants (3.4%). Ryan, Bartels, Morris, Cluff, and Gontokovsky (2009) included 2 patients with tumors in a sample of 36 participants (5.6%). Dugbartey et al. (1999, Study 2) included 1 patient with a tumor in a sample of 14 participants (7.1%). Finally, Tranel, Manzel, and Anderson (2008) included 23 postsurgery patients with tumors in a sample of 160 participants (14.4%).

On January 26, 2015, we searched again for articles on the WAIS and brain tumors in two different databases (EBSCOhost and PubMed) and applied the same

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limiters. We searched six combinations of keywords: (a) "WAIS" and "brain tumor"; (b) "WAIS" and "brain neoplasm"; (c) "WAIS" and "brain cancer"; (d) "Wechsler Adult Intelligence Scale" and "brain tumor"; (e) "Wechsler Adult Intelligence Scale" and "brain neoplasm"; and (f) "Wechsler Adult Intelligence Scale" and "brain cancer." From the final pool of 42 results, 21 articles focused on the WAIS, 11 focused on the Wechsler Adult Intelligence Scale-Revised (WAIS-R), 5 focused on the WAIS-III (Arreguin-Gonzalez et al., 2011; Motomura et al., 2014; Quik et al., 2012; Ramirez, Blonsky, Berlin, Carpentier, & Talia, 2013; Ryan et al., 2009), and 5 focused on the Wechsler Intelligence Scale for Children, Wechsler Intelligence Scale for Children-Revised, Wechsler Intelligence Scale for Children-Third Edition, or Wechsler Intelligence Scale for Children-Fourth Edition along with the WAIS, WAIS-R, or WAIS-IV. It is worth noting that these last 5 articles that used the Wechsler Intelligence Scales for children or adolescents were all focused on long-term survivors and/or long-term effects of irradiation (e.g., Calonge, 2009; Reimers et al., 2003; Watanable et al., 2011). Among the 5 articles identified with the WAIS-III, 2 were already identified in the first search (Arreguin-Gonzalez et al., 2011; Ryan et al., 2009), 1 was a case report (Motomura et al., 2014), and the remaining 2 did not use the whole battery (Quik et al., 2012; Ramirez et al., 2013).

Taking into account both searches, the performance of patients with brain tumors on adult intelligence scales were studied exclusively in the original version of the WAIS (e.g., Gregor et al., 1996; Shen et al., 2013; Whelan & Walker, 1988). This issue has not been investigated in the most recent WAIS versions (i.e., WAIS-III and WAIS-IV).

The main goal of our study was to search for a neuropsychological profile of patients with brain tumors in the Portuguese adaptation of the WAIS-III. We selected our sample prospectively, during a period of 6 months, at the most important state oncology hospital in Lisbon, the capital of Portugal.

Method

Participants

Following institutional review board approval, participants were selected from a 6-month prospective series of consecutive inpatient and outpatient referrals to the neurology service of the public oncology hospital *Instituto Português de Oncologia Francisco Gentil*, in Lisbon, according to the following criteria: (a) diagnosis of brain tumor, (b) first time in this hospital, (c) absence of prior neurological or psychiatric history, and (d) absence of prior treatment different from neurosurgery (i.e., no chemotherapy or radiotherapy). It is worth noting that these cases represent relatively freshly diagnosed patients who had moved through an organized system of care, from postsurgery to chemotherapy/radiotherapy/other treatment.

A total of 76 individuals were referred to this hospital from October 12, 2011, to April 12, 2012, but 39 individuals were excluded immediately after their first medical consultation because they did not meet the inclusion criteria or they did not agree to participate. Fourteen individuals were lost or were noncooperative after scheduling the neuropsychological assessment. All participants provided their written informed consent according to the Declaration of Helsinki. Demographics and the motives for exclusion or loss are shown in Table 1.

Table 1. Demographic information and reason for exclusion or loss.

	Excluded ($N = 39$)			Lost ($N = 14$)			Final sample ($N = 23$)		
	M	*SD*	Range	*M*	*SD*	Range	*M*	*SD*	Range
Age	54.0	18.77	10–82	74.0	13.99	25–78	54.1	16.94	24–77
Admission (days)[a]	27.3	35.09	2–189	19.6	21.27	8–92	21.8	20.67	6–92
Karnofsky Index	68.0	23.00	30–100	73.0	14.51	50–90	88.0	15.04	50–100
	%	*n*		%	*n*		%	*n*	
Gender (% Male)	64.1%	25		21.4%	3		69.6%	16	
Glioblastoma	46.2%	18		85.7%	12		47.8%	11	
Exclusion									
No tumor	10.3%	4							
Infratentorial	5.1%	2							
Noncooperative	2.6%	1		14.4%	2				
Untestable	15.4%	6		7.1%	1				
Premorbids[b]	17.9%	7		7.1%	1				
Therapy started[c]	12.8%	5		14.4%	2				
Unable to come[d]	12.8%	5		35.7%	5				
No explanation	23.1%	9		21.4%	3				

[a]Time elapsed from surgery to admission into this hospital.
[b]Neurological or psychiatric history.
[c]Chemotherapy or radiotherapy.
[d]Bedridden out of this hospital and/or with no transportation.

Brain tumor group (N = 23). The final sample included 23 patients with a single brain tumor and no history of other neurological or psychiatric diseases. All patients were assessed after brain surgery and before chemotherapy and/or radiotherapy. Sixteen patients were male and 7 were female. Patients' mean age was 54.09 years ($SD = 16.94$ years, range = 24–77 years), and their mean years of education was 9.83 ($SD = 5.56$ years, range = 4–17 years).

All patients had neuropathologically confirmed brain tumors. The etiologies of the brain tumors were: glioblastoma ($n = 11$), astrocytoma ($n = 5$), oligodendroglioma ($n = 2$), lymphoma ($n = 2$), oligoastrocytoma ($n = 1$), meningioma ($n = 1$), and glioma ($n = 1$). The tumors were lateralized in the right hemisphere in 10 cases, in the left hemisphere in 10 cases, and in a median location in 3 cases. The locations were frontal ($n = 9$), temporal ($n = 5$), posterior (occipital, parietal, occipito-parietal, and occipito-parieto-temporal, $n = 5$), median (corpus callosum or thalamus, $n = 3$) and frontotemporal ($n = 1$). The neuropsychological assessment identified: no impairment ($n = 4$), executive dysfunction ($n = 8$), aphasia ($n = 3$), visual-perceptual impairment ($n = 2$), anterograde amnesia ($n = 1$), multi-impairment or dementia ($n = 4$), and pseudodementia ($n = 1$).

Normal control group (N = 23). After the selection of the clinical sample, the control group was obtained from the WAIS-III Portuguese standardization sample. These participants were matched to the selected clinical sample in gender (16 men and 7 women), age ($M = 54.04$ years, $SD = 17.24$ years, range = 24–79 years), education ($M = 8.83$ years, $SD = 4.58$ years, range = 4–14 years), professional status (including functional demands), and region of residence (as shown in Table 2). The matched control sample had no history of either psychiatric or neurological diagnosis.

Procedures

After medical consultation, patients were invited to participate in the study. The research protocol consisted of two assessment sessions. In the first session, participants were interviewed and performed a series of cognitive tests besides the WAIS-III. The second session consisted of the WAIS-III administration and occurred within 2 weeks from the first session. All patients were assessed after neurosurgery, but before chemotherapy and/or radiotherapy, by a trained neuropsychologist. Assessments were scheduled to minimize interference with other medical services and to accommodate patients' tolerance. The first assessment occurred 10 to 108 days after neurosurgery ($M = 38$, $SD = 22.3$). All tests were administered in a clinical setting according to the manner prescribed by the test publishers. At the end, all participants received a written report of their scores and other evaluation data.

Information about medical, educational, and occupational history, drug and alcohol use, and psychiatric and psychological state was obtained from participants and/or family members. Relevant injury-related information was extracted from medical files, including etiology, localization of the injury, and the Karnofsky Index. The Karnofsky Performance Status Index, usually called the Karnofsky Index (KI), is a scale that varies every 10% from 0% (dead) to 100% (normal, no complaints). This scale is used to rate the general well-being and activities of daily life. Scores greater than 50% are attributed to patients who are not bedridden and are able to function autonomously or with minor help.

Table 2. Demographic information for patients with brain tumors and matched controls.

	Brain tumor ($N = 23$)			Matched controls ($N = 23$)			
	M	*SD*	Range	*M*	*SD*	Range	*p*
Age	54.09	16.94	24–77	54.04	17.24	24–79	.993
Education	9.83	5.56	4–17	8.83	4.58	4–14	.509
Days after surgery	38.00	22.30	10–108				

Statistical analyses

The patients with brain tumors and matched control groups were first compared on demographic variables using the *t* test and Mann-Whitney U Test.

We followed the steps of score interpretation suggested in the manual (Psychological Corporation, 1997; Wechsler, 2008), and by Kaufman and Lichtenberger (1999) and Tulsky et al. (2003): (a) an analysis of the three IQ and four index scores (i.e., Verbal IQ [VIQ], Performance IQ [PIQ], Full-Scale IQ [FSIQ], Verbal Comprehension Index [VCI], Perceptual Organization Index [POI], Working Memory Index [WMI], and Processing Speed Index [PSI]); (b) an analysis of each subtest alone and subtests by index; (c) scatter analysis to identify the strengths and weaknesses; and (d) a discrepancy analysis of the WAIS-III composite scores.

The Mann-Whitney U Test was used to compare groups, and the Cohen's *r* was used to calculate the effect size. For each family of tests (i.e., IQ scores, index scores, and subtest scores), we corrected for multiple comparisons using the Bonferroni test.

Results

Characteristics of the sample

As shown in Table 1, the excluded and lost participants had less functionality, as suggested by a higher KI. As shown in Table 2, independent-samples *t* tests indicated there were no differences between the two groups in terms of age and education, $t(44) = -0.01$, $p = .993$, and $t(44) = -0.67$, $p = .509$, respectively. Participants from both groups were matched for gender (16 men and 7 women), professional status, and geographic region where the participant lived.

IQ, index, and Digit Span Scores

Group comparisons for WAIS-III IQ, index, and subtest scaled scores for patients with brain tumors and matched control groups are reported in Table 3. Score profiles are also shown in Figures 1 and 2.

Mann-Whitney U Tests indicated VIQ and VCI scores did not differ significantly for patients with tumors and matched control groups, $Z = -1.58$, $p = .113$, and $Z = -1.10$, $p = .271$, respectively. However the brain tumor group had significant lower PIQ, FSIQ, POI, WMI, and PSI scores than the matched control group, $Z = -2.64$, $p = .008$; $Z = -2.43$, $p = .015$; $Z = -2.06$, $p = .040$; $Z = -2.76$, $p = .006$; and $Z = -2.16$, $p = .030$, respectively. Furthermore, the Cohen's effect size value suggested a moderate-to-large practical significance for the lower performance of the brain tumor group compared with the matched controls for the PIQ, FSIQ, POI, WMI, and PSI scores, $r = .39$, $r = .36$, $r = .30$, $r = .41$, and $r = .32$, respectively.

Differences in the scaled scores were not found for the two groups on 9 of the 14 subtests—namely 5 verbal and 4 performance subtests: Vocabulary ($Z = -0.243$, $p = .808$), Similarities ($Z = -0.818$, $p = .413$), Information ($Z = -1.849$, $p = .064$), Comprehension ($Z = -0.066$, $p = .947$), and Letter-Number Sequencing ($Z = -1.864$, $p = .062$), as well as Picture Completion ($Z = -1.943$, $p = .052$), Block Design ($Z = -1.670$, $p = .095$), Matrix Reasoning ($Z = -1.451$, $p = .147$), and Symbol Search ($Z = -1.620$, $p = .105$). However, group differences with a low practical significance were found on Object Assembly, Arithmetic, Picture Arrangement, Digit Span and Digit Symbol - Coding subtests, $Z = -2.99$, $p = .003$, $r = .44$; $Z = -2.94$, $p = .003$, $r = .43$; $Z = -2.69$, $p = .007$, $r = .43$; $Z = -2.46$, $p = .014$, $r = .36$; $Z = -2.45$, $p = .014$, $r = .36$, respectively. Finally, differences with a moderate practical significance were found for Digit Symbol ($Z = -2.45$, $p = .014$, $r = .36$) and Digit Span ($Z = -2.455$, $p = .014$, $r = .36$).

With Bonferroni correction, the groups remained statistically different for PIQ, FSIQ, WMI, Arithmetic and Object Assembly.

Table 3. WAIS-III scaled scores for brain tumor and matched controls.

	Brain tumor ($N = 23$)			Matched controls ($N = 23$)				
	M	*SD*	Range	*M*	*SD*	Range	*p*	Cohen's *r*
IQ Scores								
VIQ	100.26	15.40	67–125	108.39	13.25	88–136	.113	
PIQ	91.35	16.93	65–121	105.75	18.33	68–141	.008*	.39
FSIQ	95.78	17.17	67–126	107.65	15.86	76–136	.015*	.36
Indexes								
VCI	103.26	16.75	70–134	109.00	13.44	91–134	.271	
POI	94.00	15.73	68–123	105.75	17.90	69–137	.040	.30
WMI	92.13	13.88	65–115	105.65	14.31	77–132	.006*	.41
PSI	94.22	18.21	60–122	105.25	16.39	71–130	.030	.32
Subtests								
V	11.22	2.86	4–16	11.43	3.20	6–16	.808	
S	9.91	4.38	3,17	10.91	2.56	6–16	.413	
A	9.52	2.69	5–15	12.04	2.92	5–16	.003*	.43
DS	8.57	2.69	5–15	10.65	2.90	5–15	.014	.36
I	10.61	3.09	4–17	12.57	2.63	8–17	.064	.27
C	10.70	3.53	4–17	10.74	2.78	7–15	.947	
LNS	8.22	3.03	3–14	10.26	3.74	4–17	.062	.28
PC	8.35	3.11	3–14	10.85	3.59	5–17	.052	.29
CD	8.83	3.73	2–15	11.25	3.52	4–7	.014	.36
BD	9.52	2.79	3–14	11.25	3.23	5–18	.095	.25
MR	9.09	2.97	4–14	10.60	2.93	5–16	.147	
PA	8.30	2.53	4–13	10.60	2.60	6–17	.007	.40
SS	8.83	3.41	2–14	10.60	3.12	4–16	.105	
OA	8.17	3.33	2–17	11.55	2.96	7–18	.003*	.44

Note. WAIS-III = Wechsler Adult Intelligence Scale-Third Edition; FSIQ = Full-Scale IQ; VIQ = Verbal IQ; PIQ = Performance IQ; VCI = Verbal Comprehension Index; POI = Perceptual Organization Index; WMI = Working Memory Index; PSI = Processing Speed Index; V = Vocabulary; S = Similarities; A = Arithmetic; DS = Digit Span; I = Information; C = Comprehension; LNS = Letter-Number Sequencing; PC = Picture Completion; CD = Digit Symbol-Coding; BD = Block Design; MR = Matrix Reasoning; PA = Picture Arrangement; SS = Symbol Search; OA = Object Assembly.
*p values that remained significant after Bonferroni correction for multiple comparisons.

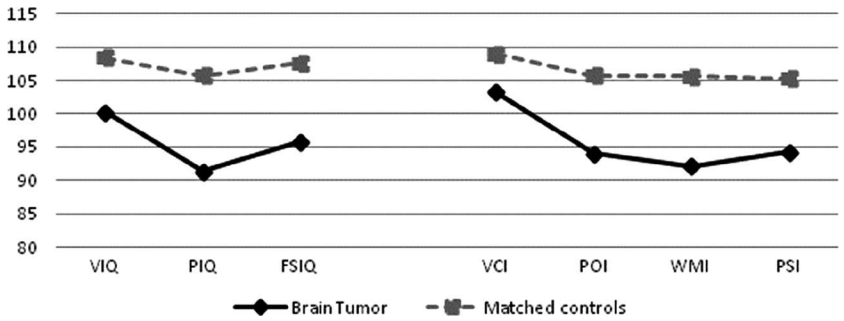

Figure 1. Mean IQ and index scores for the brain tumor and matched control groups. VIQ = Verbal IQ; PIQ = Performance IQ; FSIQ = Full-Scale IQ; VCI = Verbal Comprehension Index; POI = Perceptual Organization Index; WMI = Working Memory Index; PSI = Processing Speed Index.

Strengths and weaknesses (scatter analysis)

In the scatter analysis, the participant was compared to their own mean performance. Scatter scores were calculated according to scoring instructions in the WAIS-III manual: At first, the sum of the verbal scaled scores was divided by the number of verbal subtests administered ($n = 7$) to determine the mean verbal score. The same procedure was done to calculate the mean performance score. Then, the scatter score for each test was calculated by subtracting the mean verbal/performance score from the subtest scaled score.

Mean scatter scores for patients with brain tumors and matched control groups are reported in Table 4. Only Vocabulary and Comprehension were significantly different between groups, $Z = -1.99$, $p = .047$, $r = .29$, and $Z = -2.46$, $p = .014$, $r = .36$, respectively. Scores did not differ significantly between groups for any other subtest—namely, Similarities, Arithmetic, Digit Span, Information, Letter-Number Sequencing, Picture Completion, Digit Symbol, Block Design, Matrix Reasoning, Picture Arrangement, Symbol Search, and Object Assembly, $Z \geq -1.43$, $p \geq .153$.

Later, we compared these mean scatter scores to Table B.3.2 in Appendix B from the technical manual. When the absolute value of the difference was equal to or greater than the reference value in the table (95% level of confidence), the difference was classified as a strength (for positive values) or weakness (for negative values). Mean scatter scores of patients with brain tumors and matched control groups fell within the normal range according the norms' tables (i.e., no strengths or weaknesses were identified).

Discrepancy comparisons (composite measures)

Mean discrepancy comparisons for patients with brain tumors and matched control groups are reported in Table 5. Scores did not differ significantly between groups for any discrepancy ($p > .05$).

The mean discrepancy scores of each group were compared to the norms' Supplementary Tables B.1 (95% level of confidence). The brain tumor group's mean discrepancy scores were different from the reference scores on the VIQ–PIQ discrepancy (though the observed discrepancy score of 9.35 can be found in

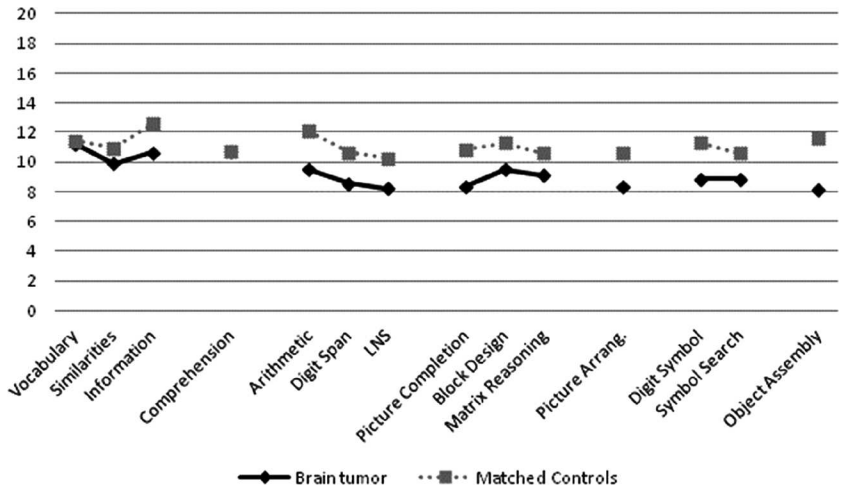

Figure 2. Mean subtest scores for brain tumor and matched control groups. LNS = Letter-Number Sequencing.

Table 4. Scatter scores (i.e., mean differences between subtest scaled scores and mean verbal/performance score) for patients with brain tumors and matched controls.

	Brain tumor ($N = 23$)			Matched controls ($N = 23$)				
	M	*SD*	Range	*M*	*SD*	Range	*p*	Cohen's *r*
Vocabulary	1.22	1.52	−2.43–4.57	0.21	1.63	−3.14–3.14	.047	.29
Similarities	0.30	2.55	−4.29–6.29	−0.36	1.91	−4.14–3.29	.339	
Arithmetic	−0.17	2.20	−4.71–3.71	0.81	2.83	−5.29–6.43	.253	
Digit Span	−0.12	2.50	−4.86–3.43	−0.53	1.17	−3.57–2.43	.262	
Information	0.79	1.59	−3.57–3.86	1.33	0.91	0.14–3.29	.169	
Comprehension	1.03	2.05	−2.57–4.86	−0.41	1.43	−3.57–1.86	.014	.36
Letter-Number Sequencing	−1.57	1.94	−5.14–1.86	−0.93	2.24	−5.86–3.00	.429	
Picture Completion	−0.32	1.73	−2.86–3.14	−0.27	2.30	−3.86–4.71	.912	
Digit Symbol	0.17	1.65	−2.86–2.43	0.44	1.72	−3.00–3.86	.307	
Block Design	0.79	1.77	−1.86–5.57	0.66	1.52	−2.29–3.00	.153	
Matrix Reasoning	0.36	1.60	−2.86–3.57	−0.26	1.63	−3.00–2.00	.180	
Picture Arrangement	−0.42	1.68	−3.43–3.29	−0.49	1.53	−3.71–2.29	.794	
Symbol Search	0.10	1.68	−3.43–3.71	−0.31	2.25	−6.29–3.29	.869	
Object Assembly	−0.50	2.15	−5.14–3.29	0.41	2.12	−2.43–6.14	.792	

38.1% of the standardization sample), VCI–POI discrepancy (though the observed discrepancy score of 9.00 can be found in 43.5% of the standardization sample), and the VCI–WMI discrepancy (though the observed discrepancy score of 10.61 can be found in 38.6% of the standardization sample).

Discussion

Patients with brain tumors performed at a lower level than the matched control participants on the PIQ, FSIQ, and WMI. However, all mean IQ and Indexes scores fell within Wechsler's normal range (i.e. 100 +/- 15). Therefore, all mean IQ and index scores should be considered "normal" according to the technical manual.

After Bonferroni correction, 3 of 14 WAIS-III subtests were statistically different between the patients with brain tumors and the matched control participants. Despite their lower performance in comparison with the control group, scaled scores of the patients with brain tumors were all within the normal range.

Additionally, patients with brain tumors had larger mean scatter scores on Vocabulary and Comprehension when compared with the matched controls, but the mean scaled scores on the Vocabulary and Comprehension subtests were not significantly different between groups. These findings (a) suggest that these two subtests might be more preserved than other subtests among patients with brain tumors, and (b) support the use of the Vocabulary subtest as a premorbid intelligence measure (Alves, Simões, & Martins, 2012). However, all mean scatter scores of the brain tumor group were within the normal range according to the technical manual. Therefore, no significant strength or weakness was identified for the patients with brain tumors.

Finally, when comparing mean discrepancy scores, no significant group differences were found. Three discrepancies were higher than expected (i.e., VIQ–PIQ, VCI–POI, and VCI–WMI), but similar scores to our tumor group are common in more than one third of the Portuguese standardization sample.

Overall, there is no WAIS-III profile or a special score that could obviously point to cognitive impairment in this brain tumor group, but there were significant differences between groups in WAIS-III performance.

A possible explanation for the absence of a specific profile is the use of mean scores in this study, which may have masked the heterogeneity of cognitive impairment associated with the diversity of brain injury

Table 5. WAIS-III discrepancy scores for patients with brain tumors and matched controls.

	Brain tumor ($N = 23$)			Matched controls ($N = 23$)			
	M	*SD*	Range	*M*	*SD*	Range	*p*
VIQ–PIQ	9.35	9.93	−19–24	3.14	12.37	−24–23	.860
VCI–POI	9.00	11.49	−24–29	4.30	12.63	−19–27	.150
VCI–WMI	10.61	15.03	−23–40	3.87	9.58	−22–22	.097
POI–PSI	0.65	10.24	−20–17	−0.67	14.35	−24–32	.647
VCI–PSI	9.22	12.63	−13–43	2.95	11.13	−22–20	.162
POI–WMI	3.57	11.83	−24–18	0.22	11.88	−19–32	.141
WMI–PSI	−1.39	13.04	−22–33	−1.05	10.44	−24–31	.760

Note. WAIS-III = Wechsler Adult Intelligence Scale-Third Edition; VIQ = Verbal IQ; PIQ = Performance IQ; VCI = Verbal Comprehension Index; POI = Perceptual Organization Index; WMI = Working Memory Index; PSI = Processing Speed Index.

locations. Future studies on the topic ought to take into account brain tumor location in the inclusion criteria, as was done in earlier versions of the WAIS (e.g., Whelan & Walker, 1988), while knowing that only lateralizing brain lesion on the right versus left hemisphere is sometimes misleading (e.g., Mattis, Hannay, & Meyers, 1992; Ryan et al., 2009). Some of these tumors may have had a slow progressive growth, which left space for the brain to readjust; and once size effect was removed through surgery, the cognitive functions may have returned to premorbid levels.

Even though patients were selected in a consecutive manner, the small sample size is an important limitation. We tried to deal with this limitation by investigating the effect size. To guarantee that patients had no other treatment aside from surgery (i.e., no chemotherapy or radiotherapy), the assessment had to be performed in the acute and postacute stages. This is a limitation because patients in the acute stage are not as cognitively stable as those in the chronic stage.

In short, the results of this study suggest that the WAIS-III is sensitive to brain tumors, but there is no profile or score that could be used as an alert sign. Cognitive impairment due to a primary brain tumor can go unnoticed even to an experienced neuropsychologist who will only follow the WAIS-III manual recommendations for score interpretation. Studies focused on brain injury location are necessary to unravel how different brain injury locations and/or different cognitive impairments affect WAIS-III performance.

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Searching for a neurologic injury's Wechsler Adult Intelligence Scale-Third Edition profile

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Searching for a neurologic injury's Wechsler Adult Intelligence Scale-Third Edition profile

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ABSTRACT

This study aimed to investigate the presence of a Wechsler Adult Intelligence Scale-Third Edition (WAIS-III) cognitive profile in a Portuguese neurologic injured sample. The Portuguese WAIS-III was administered to 81 mixed neurologic patients and 81 healthy matched controls selected from the Portuguese standardization sample. Although the mixed neurologic injury group performed significantly lower than the healthy controls for the majority of the WAIS-III scores (i.e., composite measures, discrepancies, and subtests), the mean scores were within the normal range and, therefore, at risk of being unobserved in a clinical evaluation. ROC curves analysis showed poor to acceptable diagnostic accuracy for the WAIS-III composite measures and subtests (Working Memory Index and Digit Span revealed the highest accuracy for discriminating between participants, respectively). Multiple regression analysis showed that both literacy and the presence of brain injury were significant predictors for all of the composite measures. In addition, multiple regression analysis also showed that literacy, age of injury onset, and years of survival predicted all seven composite measures for the mixed neurologic injured group. Despite the failure to find a WAIS-III cognitive profile for mixed neurologic patients, the results showed a significant influence of brain lesion and literacy in the performance of the WAIS-III.

KEYWORDS

Diagnostic accuracy; intelligence; literacy; mixed neurologic injury; Wechsler Adult Intelligence Scale – Third Edition

Introduction

The Wechsler Adult Intelligence Scale's (WAIS) predecessor was constructed in 1939, and its name was Wechsler-Bellevue (W-B) Scale (Wechsler, 1944). Sixteen years of clinical work evolved and, after some procedure changes and new norm tables, the W-B became the original WAIS (Wechsler, 1955). Another twenty-six years passed and the WAIS' norms were updated with minor item changes, turning the WAIS into the WAIS-R (Wechsler, 1981). After David Wechsler's death, the WAIS underwent two large revisions and subsequent standardizations, specifically the creation of WAIS-III (The Psychological Corporation, 1997) and WAIS-IV (The Psychological Corporation, 2008). Beyond the key of updating norms, Kaufman and Lichtenberger (1999, 2013) pointed out several overt and covert neuropsychological goals that prompted and guided the revision of both WAIS-III and WAIS-IV. Gonçalves, Simões, & Castro-Caldas (2014b, 2015) reviewed 226 papers on WAIS-III and corroborated the idea that the WAIS was eager to be more and more a neuropsychological affair.

WAIS, WAIS-R, and WAIS-III are "the single most widely used instrument for measuring intelligence today. Despite its construction as a test of cognitive aptitude, the WAIS is ubiquitous in neuropsychological batteries that assess impairments (…). It has excellent psychometric properties, very high test-retest reliability in both healthy (…) and clinical populations (…), and an enormous database to provide comparison and standardization" (Gläscher et al., 2009, p. 681). According to The Psychological Corporation (2008), Kaufman and Lichtenberger (1999), Tulsky et al. (2003), and Gonçalves et al. (2015) most of the WAIS-III validation and/or clinical research are conducted in the context of neuropsychological studies, and its most relevant work is done with Traumatic Brain Injury (TBI), temporal lobe Epilepsy, aging neurodegenerative diseases (such as, Alzheimer's, Huntington's, and Parkinson's Diseases), Mild Cognitive Impairment (MCI), Multiple

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Sclerosis, Korsakoff's Syndrome, and samples with mixed neuropsychiatric diseases. On the other hand, as reported by The Psychological Corporation (2008) and Kaufman and Lichtenberger (2013), the WAIS-IV validation studies focused on neurodevelopmental disorders (i.e., Intellectual Disability, Specific Learning Disorders, Attention Deficit Hiperactivity Disorder, among others), but they also report studies on psychiatric (i.e., Major Depressive Disorder) and neurological (i.e., TBI, MCI, and Mild Probable Alzheimer's Dementia) disorders.

From the psychometric point of view, Flynn (2009) favored WAIS-IV over WAIS-III. However, the clinical perspective of Loring and Bauer (2010), favored WAIS-III over WAIS-IV. Because there are no WAIS-IV norms for the Portuguese speaking population, our study used WAIS-III.

A large number of WAIS-III studies have observed that individuals with TBI performed lower than 85 on the Processing Speed Index (PSI) (e.g., Axelrod, Fichtenberg, Liethen, Czarnota, & Stucky, 2001; Fisher, Ledbetter, Cohen, Marmor, & Tulsky, 2000; Hawkins, 1998; Kennedy, Clement, & Curtiss, 2003; The Psychological Corporation, 1997), but the low score on PSI is also observed in the Huntington Disease (Hawkins, 1998; The Psychological Corporation, 1997) and Schizophrenia (Hawkins, 1998; The Psychological Corporation, 1997). A low PSI score is the most consistent cognitive impairment profile among the studies that used at least 11 of the 14 subtest of the WAIS-III.

There are also numerous studies that used only some subtests from the whole battery, and a few that used all subtests from a specific WAIS-III Index like Working Memory Index (WMI) (e.g., Earnst et al., 2001; Noé, Ferri, Colomer, Moliner, & Chirivella, 2010) or WMI + PSI (Bowler et al., 2001; Kennedy et al., 2003) to assess frontal lobe dysfunctions.

Therefore, the present study investigated the presence of a WAIS-III cognitive profile in Portuguese brain lesioned patients with mixed neurologic diseases. Specifically, (a) this study analyzed the presence of cognitive strengths and weaknesses in individuals with mixed neurologic injury, (b) the diagnostic accuracy of the WAIS-III to correctly discriminate between mixed neurologic injured patients and healthy matched controls, and (c) the predictive effect of mixed neurologic injury (e.g., lesion onset, years of evolution, etc.) on the WAIS-III composite measures.

Method

Participants

The participants were 81 healthy controls and 81 brain lesioned patients with mixed neurologic diseases matched for gender (37 female and 44 male), age, literacy (completed years of formal education), professional status, and geographic region. Table 1 shows the descriptive statistics for age, literacy, age at disease onset, and years of disease duration. The mixed neurologic injured group included 23 patients with primary brain tumor (for more detailed information see Gonçalves, Simões, & Castro-Caldas, 2016), 30 patients with refractory epilepsy (for more detailed information see Gonçalves, Simões, & Castro-Caldas, submitted), 20 patients submitted to brain surgery after subarachnoid hemorrhage (SAH), four TBI patients and four stroke patients with aphasia. All brain tumor and refractory epileptic patients were recruited consecutively in prospective series, but the SAH patients were mainly selected retrospectively from a long term follow-up study. Prior and/or actual neurologic or psychiatric history was considered as an exclusion criteria for both clinical (except for the refractory epileptic patients) and control groups.

In the mixed neurologic group, 73 out of the 81 participants already had or were assigned to have brain surgery. The brain injury was lateralized in the left hemisphere in 31 cases, in the right hemisphere in 34 cases, bilaterally in eight cases, and finally in the medial regions (e.g., corpus callosum or thalamus) in four cases. The mixed neurologic injury group had 76 right-handed and two left-handed subjects.

Measures and procedures

All participants were assessed after institutional review board approval and informed consent. The research protocol consisted of two psychological assessment sessions. After informed consent, in the first session, participants were interviewed and then performed a battery of cognitive tests. The second session consisted of the Portuguese WAIS-III (Wechsler, 2008) administration and occurred within two weeks from the first session. All tests were administered in a clinical setting according to the manner prescribed by the test publishers. Only psychologists with extensive experience in neuropsychological evaluation administered, scored

Table 1. Demographic information about healthy controls and mixed neurologic injured patients.

	Healthy controls ($N = 81$)			Mixed neurologic injured ($N = 81$)			t	p-
	Mean	*SD*	Range	Mean	*SD*	Range	(160)	value
Age	49.05	16.03	22–82	49.68	1.01	21–80	−0.250	.803
Literacy	8.90	4.03	0–14	9.23	4.60	0–17	−0.490	.625
Age onset				36.96	21.97	0–77		
Duration (years)				12.59	14.03	0.03–63		

and interpreted the results. All participants received a written report of their scores and other evaluation data.

Statistical analysis

Statistics were computed in SPSS Statistics 22 and MedCalc version 12.7. The patients with mixed neurologic injury and matched control groups were compared on WAIS-III composite measures (i.e., IQ and Indexes), composite measures' discrepancies, subtests' scaled scores and subtests scatter scores using *t-test*. ROC curves were performed to evaluate the contribution of each variable to accurately discriminate between mixed neurologic injured patients and healthy controls [area under the curve (AUC) values] and to identify the optimal cut-off score (Youden index *J*). The more accurately a task discriminates between groups, the higher is its AUC value. An AUC of .5 to .7 indicates poor discrimination, .7 to .8 indicates acceptable discrimination, .8 to .9 is excellent discrimination, and .9 to 1.0 indicates outstanding discrimination (Hosmer, Lemeshow, & Sturdivant, 2013). Multiple regression analysis was used to investigate the predictive effect of mixed neurologic injury (e.g., lesion onset, years of evolution, etc.) on the WAIS-III composite measures.

Results

Composite measures and discrepancies: Group differences

As showed in Table 2, mixed neurologic injured patients had significant lower composite measures (i.e., VIQ, PIQ, FSIQ, CVI, POI, WMI, and PSI) than healthy controls, $t(154) > 3.816$, $p \geq .001$. Mixed neurologic injured patients had also significant lower scores for VIQ-PIQ and CVI-WMI discrepancies, $t(158) = -2.252$, $p = .026$ and $t(150) = -3.390$, $p = .001$ respectively. However, mean scores for all composite measures and all discrepancies were within the average range of norms tables for both groups; this means that despite the statistical differences, all scores should be interpreted as normal scores.

Composite measures: Diagnostic accuracy

The results from the ROC curve analysis showed that WMI was the most relevant measure for discriminating between mixed neurologic injured and healthy matched controls, with an AUC value of .736 (i.e., a randomly selected patient with TBI will have a lower score than a randomly selected healthy matched controls approximately 73.6% of the time) (see Table 3). The remaining variables showed poor discrimination (AUC = [.5–.7]).

In addition, the Youden index was calculated (J = sensitivity + specificity −1) to analyze the optimal cut-off scores for the composite measures and discrepancy scores. The optimal cut-off score of the WMI (≤86) revealed the highest Youden index ($J = .358$), which yielded a sensitivity of 47.1% and a specificity of 88.7%.

Composite measures: Predictive effect

Multiple regression analysis was used to analyze if gender, literacy and the presence of mixed neurologic injury significantly predicted the scores of the composite measure for all participants ($n = 162$, first part of Table 4). The results of the regression indicated that the three predictors explained up to one third of the variance ($.149 < R^2 < .369$, $p < .001$). The presence of

Table 2. WAIS-III composite measures and discrepancies for mixed neurologic injured patients and healthy controls.

	Healthy controls ($N = 81$)			Mixed neurologic injured ($N = 81$)					
	Mean	*SD*	Range	Mean	*SD*	Range	*t*	df	*p*
IQ scores									
FSIQ	105.99	16.03	66–137	93.65	17.59	58–141	4.647	159	<.001
VIQ	105.96	14.15	68–160	96.79	15.65	67–133	3.913	160	<.001
PIQ	105.04	16.90	68–141	91.54	18.88	53–148	4.766	158	<.001
Indexes									
VCI	107.79	14.02	67–134	99.83	15.36	70–134	3.446	160	.001
POI	104.41	16.71	64–146	93.44	18.41	54–144	3.956	159	<.001
WMI	104.36	14.61	70–142	90.27	16.41	61–126	5.564	149	<.001
PSI	104.73	15.93	66–130	94.27	18.26	57–150	3.816	154	<.001
Discrepancies									
VIQ – PIQ	1.10	11.42	−29–31	0.026	13.60	−23–40	−2.252	158	.026
VCI – POI	3.75	12.58	−30–34	0.246	15.10	−34–40	−1.165	158	.246
CVI – WMI	3.57	12.33	−22–44	0.001	15.05	−23–77	−3.390	150	.001
POI – PSI	−0.71	14.76	−66–32	0.759	13.04	−21–60	−0.307	155	.759
VCI – PSI	2.78	14.88	−33–50	0.123	17.22	−29–77	−1.552	155	.123
POI – WMI	−0.25	14.83	−36–42	0.053	16.60	−44–60	−1.953	150	.053
WMI – PSI	−0.62	14.27	−41–29	0.110	15.32	−30–42	1.608	148	.110

Notes. VIQ = Verbal IQ; PIQ = Performance IQ; VCI = Verbal Comprehension Index; POI = Perceptual Organization Index; WMI = Working Memory Index; PSI = Processing Speed Index.

Table 3. ROC curve analysis for the composite measures and discrepancies.

	AUC	Optimal cut-off score	Youden index	Sensitivity	Specificity
Composite measures					
FSIQ	.702	≤103	.328	74.4	58.7
VIQ	.667	≤99	.271	60.5	66.7
PIQ	.704	≤104	.325	80.0	52.5
VCI	.654	≤97	.271	48.1	79.0
POI	.675	≤82	.258	33.3	92.5
WMI	.736	≤86	.358	47.1	88.7
PSI	.685	≤90	.303	48.1	82.3
Discrepancies					
VIQ – PIQ	.598	>11	.193	37.0	82.3
VCI – POI	.559	>10	.141	42.0	72.2
CVI – WMI	.644	>14	.256	38.0	87.7
POI – PSI	.514	<−22	.088	0.0	91.1
VCI – PSI	.564	>−2	.161	74.4	41.8
POI – WMI	.598	>2	.237	62.0	61.7
WMI – PSI	.596	≤−7	.177	50.7	67.1

Notes. VIQ = Verbal IQ; PIQ = Performance IQ; VCI = Verbal Comprehension Index; POI = Perceptual Organization Index; WMI = Working Memory Index; and PSI = Processing Speed Index.

mixed neurologic injury and literacy were significant predictors for all outcomes.

In addition, multiple regression analysis was also used to analyze if the literacy, age of lesion onset and years of disease presence significantly predict the mixed neurologic injured group' scores of each composite measure ($n = 81$, second part of Table 4). The results of the regression analysis indicated that literacy, age of onset and years of evolution explained from 22% to 59.9% of the total variance and were significant predictors for all composite measures.

Subtests: Group differences

As showed in the Table 5, mixed neurologic injured patients had significant lower scaled scores than the healthy controls for the majority of the subtests, the

Table 4. Multiple regression analysis for the seven composite measures.

Total sample	Predictors	R^2	F(df)	p	β	t	p
FSIQ	Gender	.299	$F(3,157) = 22.338$	<.001	.034	0.502	.617
	Literacy				.422	6.311	<.001
	Brain lesion				−.359	−5.376	<.001
VIQ	Gender	.300	$F(3,158) = 22.587$	<.001	.071	1.063	.289
	Literacy				.455	6.833	<.001
	Brain lesion				−.313	−4.702	<.001
PIQ	Gender	.245	$F(3,156) = 16.855$	<.001	−.018	−0.252	.802
	Literacy				.345	4.957	<.001
	Brain lesion				−.365	−5.237	<.001
VCI	Gender	.369	$F(3,158) = 30.736$	<.001	−.001	−.011	.991
	Literacy				.548	8.655	<.001
	Brain lesion				−.284	−4.490	<.001
POI	Gender	.179	$F(3,157) = 11.409$	<.001	.022	.305	.761
	Literacy				.298	4.115	<.001
	Brain lesion				−.309	−4.269	<.001
WMI	Gender	.296	$F(3,146) = 20.475$	<.001	.076	1.095	.275
	Literacy				.345	4.965	<.001
	Brain lesion				−.436	−6.269	<.001
PSI	Gender	.211	$F(3,152) = 13.538$	<.001	−.123	−1.712	.089
	Literacy				.333	4.612	<.001
	Brain lesion				−.301	−4.176	<.001
Mixed neurologic injured	**Predictors**	R^2	F(df)	p	β	t	p
FSIQ	Literacy	.417	$F(3,76) = 18.144$	<.001	.627	6.526	<.001
	Lesion onset				.678	5.375	<.001
	Years of evolution				.439	3.466	.001
VIQ	Literacy	.478	$F(3,76) = 23.166$	<.001	.652	7.161	<.001
	Lesion onset				.674	5.645	<.001
	Years of evolution				.327	2.726	.008
PIQ	Literacy	.277	$F(3,75) = 9.562$	<.001	.512	4.751	<.001
	Lesion onset				.578	4.076	<.001
	Years of evolution				.472	3.316	.001
VCI	Literacy	.595	$F(3,76) = 39.623$	<.001	.798	10.142	<.001
	Lesion onset				.632	6.123	<.001
	Years of evolution				.336	3.245	.002
POI	Literacy	.220	$F(3,76) = 7.166$	<.001	.456	4.103	<.001
	Lesion onset				.518	3.548	.001
	Years of evolution				.423	2.887	.005
WMI	Literacy	.352	$F(3,66) = 11.947$	<.001	.417	3.890	<.001
	Lesion onset				.736	5.148	<.001
	Years of evolution				.381	2.628	.011
PSI	Literacy	.291	$F(3,72) = 9.829$	<.001	.457	4.236	<.001
	Lesion onset				.648	4.614	<.001
	Years of evolution				.573	4.066	<.001

Notes. VIQ = Verbal IQ; PIQ = Performance IQ; VCI = Verbal Comprehension Index; POI = Perceptual Organization Index; WMI = Working Memory Index; PSI = Processing Speed Index.

Table 5. WAIS-III substest scaled scores for mixed neurologic injured patients and healthy controls.

	Healthy controls ($N = 81$)			Mixed neurologic injured ($N = 81$)					
	Mean	*SD*	Range	Mean	*SD*	Range	*t*	df	*p*
Vocabulary	11.12	3.12	3–16	10.73	2.87	4–17	0.840	160	.402
Similarities	10.84	2.71	5–17	9.46	3.45	1–17	2.835	152	.005
Arithmetic	10.77	3.10	4–16	8.49	3.23	1–15	4.566	159	<.001
Digit span	10.81	2.68	5–19	8.27	3.19	3–17	5.499	160	<.001
Information	11.79	3.11	4–19	9.67	3.38	3–17	4.164	160	<.001
Comprehension	10.68	2.77	4–10	10.30	3.32	3–17	0.797	160	.427
LNS	10.81	3.26	4–17	8.33	2.86	3–14	4.975	151	<.001
Picture completion	10.81	3.04	4–17	8.27	3.41	1–15	5.009	160	<.001
Digit symbol coding	11.01	3.39	4–17	8.59	3.55	2–19	4.436	160	<.001
Block design	10.64	3.13	4–18	9.31	3.53	2–18	2.543	160	.012
Matrix reasoning	10.59	3.13	4–19	9.09	3.34	2–19	2.962	160	.004
Picture arrangement	10.98	3.18	3–17	8.41	2.97	2–16	5.294	159	<.001
Symbol search	10.82	2.99	3–16	9.11	3.60	2–19	3.235	153	.001

Notes. LNS = Letter Number Sequencing.

exceptions were Vocabulary and Comprehension, $t(160) = 0.840$, $p > .402$ and $t(160) > 0.797$, $p = .427$, respectively. Although inferential analysis showed that healthy controls outperformed mixed neurologic injured patients in the WAIS-III subtests, the scaled scores of the mixed neurologic injury group were within norm. Once all scores should be interpreted as normal scores, they are at risk of being unobserved in clinical evaluation.

Subtests: Diagnostic accuracy

The results from the ROC curve analysis demonstrated that Digit Span was the most relevant subtest for discriminating between mixed neurologic injured patients and healthy controls, with an AUC value of .736 (see Table 6). The remaining subtests showed poor discrimination.

The Youden index ($J = \text{sensitivity} + \text{specificity} - 1$) for the WAIS-III subtests was also computed to analyze the optimal cut-off scores. The optimal cut-off score of the Digit Span (≤ 8) revealed the highest Youden index ($J = .370$), yielding a sensitivity of 54.3% and a specificity of 82.7%.

Table 6. ROC curve analysis for the subtests scaled scores.

Subtest	AUC	Optimal cut-off score	Youden index	Sensitivity	Specificity
Vocabulary	.554	≤10	.148	46.9	67.9
Similarities	.621	≤9	.284	51.9	76.5
Arithmetic	.694	≤9	.341	65.0	69.1
Digit span	.736	≤8	.370	54.3	82.7
Information	.680	≤10	.296	61.7	67.9
Comprehension	.527	≤5	.086	9.9	98.8
Letter number sequencing	.715	≤9	.340	65.3	68.7
Picture completion	.708	≤10	.308	76.5	54.3
Digit symbol coding	.696	≤9	.321	60.5	71.6
Block design	.610	≤11	.185	72.8	45.7
Matrix reasoning	.630	≤10	.197	71.6	48.1
Picture arrangement	.723	≤8	.355	54.3	81.2
Symbol search	.660	≤10	.306	73.7	57.0

Subtests: Scatter analysis

In the scatter analysis each participant is compared to his own mean performance. Scatter scores were calculated according to scoring instructions in the WAIS-III manual. First, the scatter score was calculated by subtracting the mean of the verbal or performance subtests from each subtest scaled score. Scatter scores' results are presented in the first part of Table 7. Second, we compared these scatter scores to Table B.3.2 in Appendix B from the WAIS-III technical manual. When the absolute value of the difference was equal to or greater than the reference value in the table (95% level of confidence), the difference was classified as strength (for positive values) or weakness (for negative values). Strengths and weaknesses were calculated for each participant and their counting is presented in the first part of Table 7.

Once again, for scatter scores presented in the second part of Table 7, there were two of the CVI subtests (i.e., Vocabulary and Comprehension), and two of the WMI subtests (i.e., Digit Span and Letter Number Sequencing) that had significantly different scatter scores, $t(160) = -4.964$, $p < .001$; $t(150) = -4.713$, $p < .001$; $t(148) = 2.861$, $p = .005$; and $t(154) = 3.335$, $p = .001$, respectively. Nevertheless, according to the norm tables these mean differences are not clinically relevant.

The frequency of strengths and weaknesses are presented in the second part of Table 6. Vocabulary and Comprehension appeared more frequently as strength for the mixed neurologic injured patients than for the matched controls. Table 6 also showed that the Matrix Reasoning subtest is frequently strength for the healthy control group and weaknesses for the mixed neurologic injured group.

Table 7. WAIS-III scatter analysis for mixed neurologic injured patients and healthy controls.

	Healthy controls ($N = 81$)			Mixed neurologic injured ($N = 81$)					
	Mean	*SD*	Range	Mean	*SD*	Range	*t*	*df*	*p*-value
Vocabulary	0.15	1.58	−4.86–3.14	1.35	1.50	−3.00–7.43	−4.964	160	<.001
Similarities	−0.14	1.78	−416–4.14	0.19	2.26	−6.57–6.29	−1.009	160	.315
Arithmetic	−.021	2.43	−6.71–6.43	−0.75	2.22	−8.00–4.33	1.480	160	.141
Digit span	−0.16	1.67	−3.57–4.14	−1.05	2.24	−6.14–3.71	2.861	148	.005
Information	0.82	1.71	−4.43–6.43	0.34	1.84	−3.57–7.50	1.711	158	.089
Comprehension	−0.32	1.55	−5.43–4.00	1.01	2.01	−3.57–4.86	−4.713	150	<.001
LNS	−0.16	2.32	−5.86–4.43	−1.35	2.12	−8.50–3.00	3.335	154	.001
Picture completion	0.02	2.04	−5.00–5.29	−0.45	1.77	−4.83–5.67	1.612	160	.109
Digit symbol coding	0.23	2.19	−5.00–6.29	−0.13	1.75	−4.83–3.33	1.143	160	.255
Block design	−0.14	1.47	−3.71–3.00	0.56	1.83	−4.33–5.57	−2.710	160	.007
Matrix reasoning	−0.19	1.89	−4.57–3.71	0.34	1.77	−3.50–4.00	−1.839	160	.068
Picture arrangement	0.16	2.28	−4.71–8.43	−0.24	1.86	−4.83–4.33	1.512	159	.133
Symbol search	0.08	1.88	−6.29–4.00	0.23	1.68	−3.43–5.17	−0.511	154	.610

	Weakness	Average	Strength	Weakness	Average	Strength
Vocabulary	5 (6%)	71 (88%)	5 (6%)	3 (4%)	58 (72%)	20 (24%)
Similarities	6 (7%)	71 (88%)	4 (5%)	6 (7%)	65 (80%)	10 (12%)
Arithmetic	10 (12%)	64 (79%)	7 (9%)	14 (17%)	63 (78%)	4 (5%)
Digit span	6 (7%)	73 (90%)	2 (3%)	24 (30%)	53 (65%)	4 (5%)
Information	3 (4%)	70 (86%)	9 (11%)	6 (7.5%)	69 (85%)	6 (7.5%)
Comprehension	6 (7%)	72 (89%)	3 (4%)	2 (2%)	63 (78%)	16 (20%)
LNS	5 (6%)	71 (88%)	5 (6%)	14 (19%)	61 (81%)	0 (0%)
Picture completion	7 (8%)	71 (88%)	3 (4%)	8 (10%)	71 (88%)	2 (2%)
Digit symbol coding	3 (4%)	72 (89%)	6 (7%)	4 (5%)	77 (95%)	0 (0%)
Block design	1 (1%)	80 (99%)	0 (0%)	2 (2%)	72 (89%)	7 (9%)
Matrix reasoning	11 (14%)	64 (79%)	6 (7%)	3 (4%)	65 (80%)	13 (16%)
Picture arrangement	4 (5%)	73 (91%)	3 (4%)	2 (2.5%)	77 (95%)	2 (2.5%)
Symbol search	2 (2%)	74 (94%)	3 (4%)	0 (0%)	74 (96%)	3 (4%)

Notes. LNS = Letter Number Sequencing.

Discussion

All composite measures were statistically different between the two groups, but none of these differences had clinical relevance, because they were all within Wechsler's normal range classification. Only WMI had acceptable sensitivity and specificity values. Only two discrepancy scores (i.e., VIQ-PIQ and CVI-WMI) were statistically different between groups, but their sensitivity and specificity values demonstrated poor accuracy to discriminate between acquired brain injury patients from healthy controls. At the subtest level, all subtests scaled scores except Vocabulary and Comprehension were statistically different between groups, and again both groups had all mean scores within the normal range. Only Digit Span subtest had an acceptable diagnostic accuracy. Finally, different scatter (strengths/weakness) scores' profiles between the two groups were found for Digit Span, Letter Number Sequencing and Matrix Reasoning subtests. Taken together, the results of the present study failed to find a clinical useful profile for mixed neurologic injury, because, even though there are significant differences among groups, all mean scores were within the normal range.

Many neuropsychologists use Digit Span and Letter Number Sequencing to assess frontal lobe dysfunction. In fact, MacPherson, Della Sala, Cox, Girardi, and Iveson (2015) presented the Digit Span backwards as a good test for assessing Working Memory. Although impossible to associate to a specific brain lesion, our data is consistent with the idea that Digit Span and WMI are acceptable measures to search for mixed neurologic injury.

Back to 1939, the Wechsler-Bellevue (W-B) Scale was constructed, and its "aim was not to produce a set of a brand new tests but to select, from whatever source available, such a combination of them as would best meet the requirements of an effective adult scale" (Wechsler, 1944, p. 76). Since its beginning, a vast quantity of research consolidated the use of the various versions of the WAIS across clinical settings. However, the idea that Wechsler's measures have limited neuropsychological usefulness is not new. Forty years ago, John McFie (1975) once wrote that "it is perhaps a matter of luck that many of the Wechsler subtests are neurologically relevant. They are evidently not designed with this purpose in mind; yet it follows (…) that tests based on the major group factors of ability are likely to be sensitive to lesions in specific cerebral areas" (p. 14). Thirteen years later, Lezak (1988) offered a funeral oration to the intelligence quotient (IQ) concept, but another twenty years passed and two of the most important neuropsychological assessment handbooks (Lezak, Howieson, Bigler, & Tranel, 2012; Strauss, Sherman, & Spreen, 2006) still report the survival of the Wechsler Adult Intelligence Scales as the most frequently used intelligence measure in the neuropsychological batteries.

Our study aimed to find the utility of the Portuguese WAIS-III on the assessment of cognitive impairments in brain lesioned patients with mixed neurologic diseases. The regression analysis unquestionably indicated that the presence of mixed neurologic injury, the age of disease onset, years of disease duration, and literacy affected WAIS-III performance. The effects of literacy on WAIS performance were reported since its creation (Wechsler, 1944), and have been studied more recently for WAIS-III (Colom, Abad, García, & Juan-Espinosa, 2002). In some countries other than Portugal, norm tables corrected for literacy can be purchased separately from the test manual. We tried to minimize literacy effects by matching controls in literacy. Still, the way literacy may function as a cognitive reserve on WAIS-III was not easy to interpret in our data. More detailed work is needed on this topic.

If mixed neurologic injury and literacy both influence WAIS-III performance, why did we not find clinical useful differences? A logical argument is that different brain locations contribute differently to the same cognitive functions. Once there was no homogeneity for brain lesion locations in our sample, strength of one patient may be canceled by the weakness of another, and when we look at mean scores, some deficits may be masked by the group average. To avoid this study limitation, we suggest that future studies should plan their samples based on brain lesion location, rather than on brain diseases.

The first attempts to study brain locations with the various version of the WAIS, compared right versus left brain lesion. An exhaustive review of these studies was done by Kaufman and Lichtenberger (2006), who clearly revealed that the VIQ-PIQ discrepancy consistently predicted in which side of the brain the lesion took place, but only if the Wechsler-Bellevue Scale was used. With WAIS-III, Ryan, Bartels, Morris, Cluff, and Gontkovsky (2009) with a United States sample, and Gonçalves, Simões, and Castro-Caldas (2014a) with a Portuguese sample, failed the identification of lateralized lesions. Therefore, homogenous brain lesion location samples (e.g., Gläscher et al., 2009; Tranel, Manzel, & Anderson, 2008) are needed to study the correlations of specific WAIS-III deficits with neurologic injuries in specific brain locations.

In sum, although WAIS-III performance is proved to be influenced by the presence of mixed neurologic injury, it may continuously fail to detect it if norms are not corrected for literacy and the research paradigm does not change from studying neurologic diseases to studying specific brain locations or specific cognitive impairments,.

We planned and searched for differences in this study, but it turned out that one of the most important issues that emerged from our data was the issue of a nonsignificant statistical difference. Vocabulary turned out to have the same performance profile for the two groups, both at the scaled score and the scatter score levels of the analysis. This fact made Vocabulary a good candidate for a premorbid intelligence measure. What if Vocabulary alone could estimate the premorbid IQ? A large amount of time could be saved in the neuropsychological assessment and this could be a useful clinical finding. This idea again is not new (Schoenberg, Lange, Marsh, & Saklofsky, 2011; Yates, 1956) and we are already working on this topic in a different article.

In short, despite the small sample size, with a mixed of neurologic diseases and lack of homogeneity in brain lesion locations, our data reveals significant lower performance of the mixed neurologic injury group when compared to a matched healthy control group. Multiple regression analysis confirms the presence of mixed neurologic injury as a predictor of the WAIS-III's IQs and Indexes. However, all mean scores were within the normal range, what would have made mixed neurologic injury stay unnoticed, even to an experienced neuropsychologist. Further work is needed in creating norms corrected for literacy and in redefining what is important in sample selection. It is our strong belief that we should abandon diseases' etiologies from the sample inclusion criteria, and start focusing on brain lesion locations as the key variable.

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